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THESIS

A COLLISION-PREVENTION EXPERT SYSTEM
FOR A NAVY OFFICER OF THE DECK

by

Terry W. Lewallen

March 1987

Thesis Advisor:

Neil C. Rowe

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A Collision-Prevention Expert System
for a Navy
Officer of the Deck

by

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

The goal of this thesis is to automate recommendations to the Officer of the Deck when decisions are made concerning situations that involve risk of collision. A rule-based expert system is designed and implemented as a solution to this task. The rules are based on regulations in the U.S. Coast Guard manual, *Navigation Rules International-Inland*. The expert system receives facts that describe the current situation, then searches the rule base for matching rules. The searching method is a hybrid form of forward chaining that searches cyclically through the rule base until all matches, intermediate and final, are located. The conclusions of the matching rules are displayed as a recommendation to the system user. The resulting system provides a valuable input to the Officer of the Deck, serving to increase the speed and reliability of the final decision by removing the necessity of manually looking up regulations or relying on memorization.

*Tree
130*

THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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I. INTRODUCTION

The International Regulations for Preventing Collisions at Sea, 1972 (commonly called the 72 COLREGS) must be followed by all public and private vessels of the United States while navigating upon the high seas. The Navigation Rules For Harbors, Rivers, and Inland Waters and the Pilot Rules For Inland Waters govern vessels within specified inland waters of the United States. All of these rules are contained in [Ref. 1] henceforth referred to as CG-169. Much like the traffic laws that regulate the manner in which we operate vehicles on the streets and highways, CG-169 regulates the navigation of ships in international and inland waters:

These navigation requirements have the primary purpose of preventing collisions between vessels. It is imperative that all persons operating vessels be knowledgeable of them. Strict compliance is necessary to insure the safety of vessels and passengers. [Ref. 1: p. ii]

As the person responsible for the safe navigation of Navy ships at sea, the Officer of the Deck must make sound maneuvering decisions when operating within sight of other vessels or under restricted visibility conditions. Numerous data are collected which describes the current situation. Then the situation is compared to the various rules in CG-169 which may apply. The applicable rules must be used together to arrive at the correct maneuvering decision. The entire process from data collection to decision making can often be time consuming and difficult to follow. Quite often, the Officer of the Deck uses CG-169 from memory, which introduces an increased risk of mistake.

This study will examine the use of an automated system to provide the Officer of the Deck with a fast, reliable recommendation to use in the decision-making process described above. We chose to build a particular kind of automated system referred to as a rulebased expert system. An expert system "mimics human reasoning by generating prospective solutions to a stated problem, then identifying the most likely candidate." [Ref. 2] Most rule-based expert systems consist of three main elements: a rule base, an inference engine, and a user interface. The rule base is a collection of rules relating to a particular subject. The rules are usually in the form of IF...THEN statements as shown in Figure 1.1.

```
IF
  TIME = DAY.
  TARGET ANGLE IS PORT FWD.
  RELATIVE BRG IS STBD FWD.
THEN
  YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.
  TURN STBD IF POSSIBLE.
  SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.
```

Figure 1.1 Sample IF...THEN Rule.

The inference engine compares current facts to the rule base and provides corresponding conclusions. The user interface allows communication between the user and the system.

Although mankind has long pondered the human problem solving method, serious attempts to build machines that model human reasoning were not made until the 1960's. Alan Newell and Herbert Simon were two of the earliest researchers in the area of expert computer programs. Their program, General Problem Solver (GPS), was one of the first to use rules as a basis for solving problems. [Ref. 3] Also in the 1960's, Stanford University produced a mass-spectrography expert system that was used to isolate organic compounds. Probably the most famous of the early expert systems, MYCIN, was also developed at Stanford by the Heuristic Programming Project (HPP). MYCIN could provide a systemic diagnosis of bacterial infections and recommend an effective therapeutic regimen. The knowledge base and simple rule-based processing method that formed the framework of MYCIN has become the working model for most modern expert systems. [Ref. 4] The wide range of applications for expert systems coupled with their increasing popularity suggests that expert systems may very soon become a part of our everyday existence.

Every possible situation involving risk of collision between vessels at sea can be described by a small set of facts. However, numerous combinations of facts are possible, resulting in numerous, but a finite number of possible situations. The regulations in CG-169 govern every situation, but the process of matching the

facts to the proper regulations is not always simple. "The human mind can weigh only seven possibilities at any one time, it's said, but a computer program can consider several hundred." [Ref. 5]

The decision to use an expert system as a solution to this task is based on criteria as stated by D.A. Waterman. He says that the existence of genuine experts is one of the criteria necessary for the effective use of an expert system. He further states that these experts must agree on their solutions. The expertise used for the development of this system is provided by a panel of navigation experts who are convened periodically by the United Nations to update the existing regulations. These regulations are published in CG-169. However, it could be argued that the real experts are the commanding officers of the vessels. Although they are not allowed to make their own interpretations of the regulations, they are the individuals responsible for the safety of their vessels, and who use CG-169 to prevent collisions. Waterman also states as an additional criteria that a task should require only cognitive skills. The task that this thesis tries to solve requires purely cognitive skills with no physical manipulation required. [Ref. 6]

Specially, a rule-based expert system was chosen as a solution due to the nature of the task involved. The description of a meeting situation between two vessels and the corresponding conclusion, in accordance with CG-169, fit easily into the IF...THEN format used in most rule-based systems. Also, this task is well-suited to the concept of forward chaining that is used in rule-based systems. Forward chaining is the process by which a collection of facts can be used to infer one of several conclusions by matching the IF part of a rule in the rule base. Since this task requires that a conclusion must be made from a collection of facts, the rule-based expert system using forward chaining was selected for this task.

It is not suggested that this expert system should become the sole input to this decision-making process, instead it should be considered a recommendation to assist in reaching prompt, correct decisions.

This study will attempt to answer the following questions concerning the use of expert systems:

1. Can the regulations in CG-169 be expressed in a symbolic form that will allow them to be utilized in a rule base for an expert system?
2. Can an expert system provide prompt, correct recommendations to the Officer of the Deck in a user-friendly way?

These questions are addressed in Chapter III, a report of an expert system design, and are answered in Chapter V, summary and conclusions. Chapter II provides a background on the use of CG-169 by a typical Navy bridge watch-team. Chapter IV discusses testing methods that were used. Appendix A shows interactive sessions with the system in variety of situations, Appendix B is the source code listing of the program, and Appendix C and Appendix D show the international and inland rule bases, respectively, in coded and decoded format.

II. BACKGROUND

A. RISK OF COLLISION

To better understand the manner in which a Navy Officer of the Deck utilizes CG-169, it is necessary to have a general knowledge of the regulations contained in CG-169. This chapter provides a basic discussion of those regulations.

Since the main purpose of CG-169 is the prevention of collisions, it is important to understand how the risk of collision is determined. CG-169 states "such risk shall be deemed to exist if the compass bearing of an approaching vessel does not appreciably change." [Ref. 1: p.10] Risk of collision can be determined either visually or by use of radar.

B. MEETING SITUATIONS

CG-169 defines three meeting situations that are possible when the risk of collision exists. Vessels at sea are said to be meeting when their present course and speed result in the vessels coming within a short distance of each other or, if no action is taken, result in a collision. Although there are differences in the specific wording of the international and inland regulations, both sets of regulations define the same three situations. Both definitions will be referenced, but only one will be quoted.

The head-to-head situation exists when "vessels are meeting on reciprocal or nearly reciprocal courses." [Ref. 1: pp.18,117] The phrase "reciprocal courses" describes the situation where two vessels are steering courses that are exactly opposite of each other. The overtaking situation exists when a vessel is "coming up with another vessel from a direction more than 22.5 degrees abaft her beam," where the phrase "coming up with another vessel" describes the action of one vessel approaching another from the rear, and the phrase "22.5 degrees abaft her beam" means that a vessel is approaching at an angle greater than 22.5 degrees beyond an imaginary line that would run through the center of the vessel being overtaken and be perpendicular to its' course. [Ref. 1: pp.16,119] The crossing situation exists when "vessels are approaching each other at right angles or obliquely . . . , other than when one steam vessel is overtaking another." [Ref. 1: pp.18,125]

The regulations in CG-169 are designed for meeting situations between only two vessels. If shipping traffic other than the vessel that currently poses a risk of collision

could potentially also pose a risk of collision, the maneuvering decisions must be made individually in the order of the next vessel that will pose the most eminent risk of collision.

C. TARGET ANGLE

The meeting situations defined above are normally determined visually. An important factor in determining the meeting situation is the visual aspect, or target angle, of the approaching vessel. The target angle is usually determined by estimating the compass bearing of the observer's vessel relative to the approaching vessel's course. The estimation is made by means of visual sighting in daylight hours and by observing standard lighting configurations at night. The lighting configurations are defined in CG-169 and shown here in Figure 2.1. The meeting situation is then determined by combining the target angle of the approaching vessel with its' compass bearing relative to the heading of the observer's vessel.

D. GIVEWAY AND STANDON DESIGNATIONS

CG-169 assigns a specific status to each of the vessels involved in the meeting situations defined above. For crossing and overtaking situations, one vessel is assigned the status of giveway vessel and is "directed to keep out of the way" of the other vessel, [Ref. 1: pp.18,119] while the other vessel is assigned the status of standon vessel and "shall keep her course and speed". [Ref. 1: pp.20,118] For the head-to-head situation, both vessels are assigned giveway status. [Ref. 1: pp.18,117]

E. SPECIAL STATUS OF VESSELS

The international regulations also define a special status for:

- vessels not under command
- vessels restricted in their ability to maneuver
- vessels engaged in fishing
- vessels engaged in trawling
- sailing vessels under sail
- vessels constrained by their draft

CG-169 defines special lighting configurations for the hours from sunset to sunrise and dayshapes for the remaining hours that signal a vessel's special status. The vessel with a special status will always be assigned the status of standon vessel regardless of the status that would have normally been assigned. The one exception to this regulation

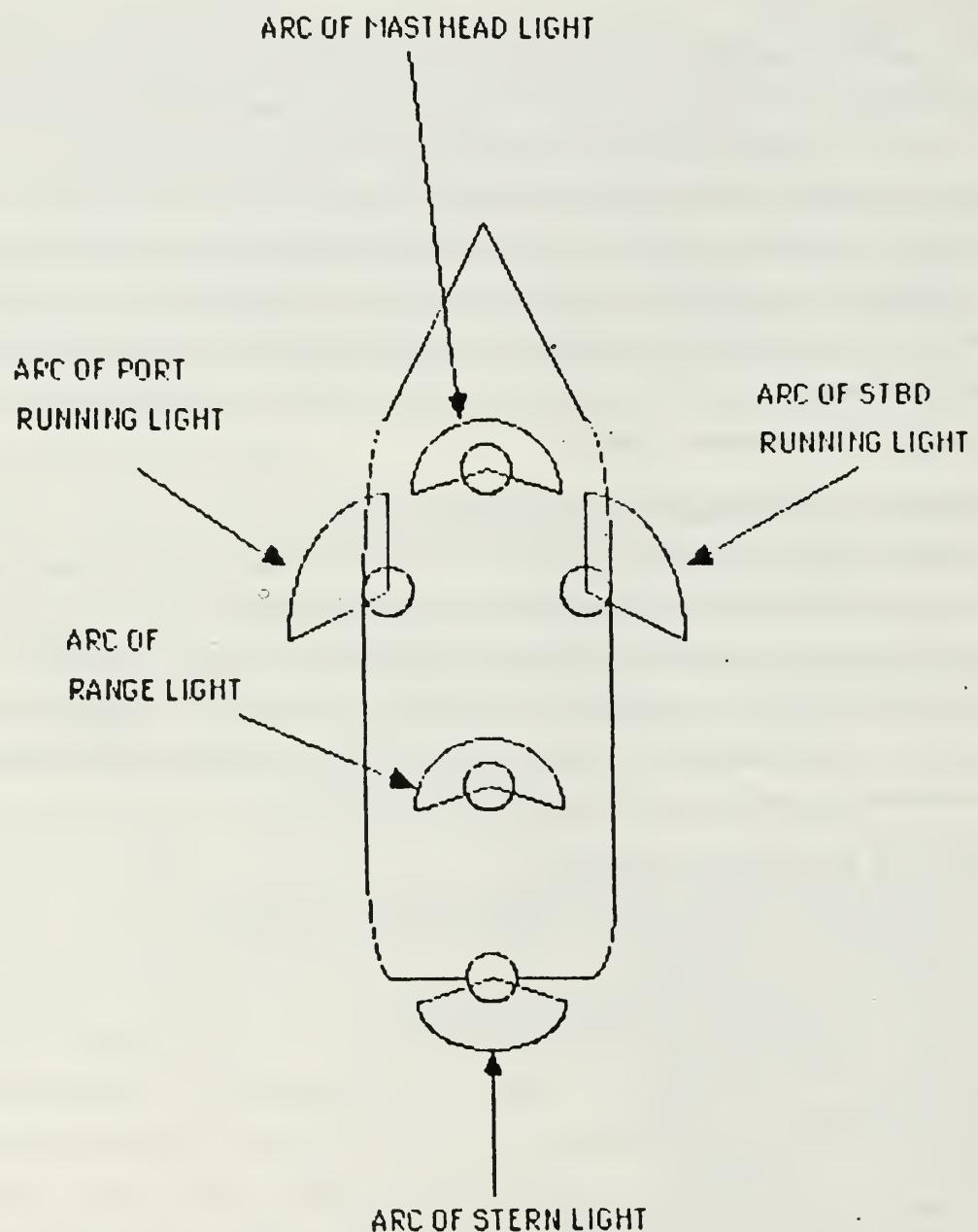


Figure 2.1 Standard Lighting Diagram.

occurs when a vessel with special status is overtaking another vessel in which case the normal regulation is invoked. [Ref. 1: pp.20,22] Determination of standon, giveaway, and special status, if it exists, in every meeting situation is necessary to ensure the safe passage of both vessels.

F. SPECIAL TASKING IN INLAND WATERS

The inland regulations specify five vessel tasks which require special attention or action from approaching vessels. These tasks are:

- laying cable
- dredging
- servicing navigation aids
- towing of submerged objects
- vessels at anchor

Special lighting configurations and dayshapes are defined for these tasks.

G. RESTRICTED VISIBILITY

CG-169 contains regulations that define proper conduct of vessels in or near areas of restricted visibility. Both sets of regulations define similar conduct situations where a vessel hears the fog signal of another vessel, but only the international regulations define conduct for the situation where a vessel detects another vessel by radar alone. [Ref. 1: pp.22,116]

H. ACTION BY THE OFFICER OF THE DECK

When the risk of collision is determined, the Officer of the Deck must promptly review all data pertinent to the situation. There are various sources for this data including visual and radar detection. Target angle and special status can be determined visually, night or day, if visibility conditions permit. Data from radar equipment can be utilized on a manual plotting device called a maneuvering board. Any changes in the distance to a vessel and/or the compass bearing of a vessel are plotted on the maneuvering board and provide a trace of the relative motion between the two vessels. The maneuvering board also provides the course, speed, closest point of approach, and target angle of an approaching vessel. Once all available data has been collected, the Officer of the Deck, by some method, references CG-169 to determine the proper action for the current situation.

Automated systems exist, and are used onboard Naval ships, that provide recommendations to avoid collision. The recommendations from these systems are good input into the decision-making process, but they do not take into account the regulations in CG-169. These automated systems, such as the Collision Avoidance System developed by Raytheon, allow only a minimum-distance parameter as input, then the system will give recommendations to maintain that minimum distance from any approaching vessel. However, the recommendation does not consider which of the two vessels should actually maneuver, so the Officer of the Deck must reference CG-169 before the recommendation can be followed. The expert system discussed in Chapter I, with its reference to CG-169 would be a valuable, additional input to the Officer of the Deck.

III. DESIGN AND IMPLEMENTATION

A. PROBLEM STATEMENT

As stated in Chapter I, when a risk of collision exists, the Officer of the Deck must review the data that describes the meeting situation, then reference CG-169, either literally or by memory, to determine the proper course of action that will prevent a collision. This process can be time-consuming and prone to error, especially if the Officer of the Deck relies heavily upon his memorization of CG-169. The goal of this thesis is to design and implement a rule-based expert system that will assist the Officer of the Deck in making prompt, correct maneuvering decisions when the risk of collision exists.

This expert system should receive as input data, a set of facts that describe the meeting situation, and it should provide as output, intermediate conclusions that interpret dayshapes and special lighting patterns and also, final conclusions that serve as input to the Officer of the Deck for use in making correct maneuvering decisions.

B. FUNCTIONAL SPECIFICATIONS

1. Rule Base

The rule base, or knowledge representation, in a rule-based expert system consists of a set of rules that are able to make recommendations or decisions when compared to a set of facts that describe a certain situation. The rule base in this expert system will be a collection of rules that equate to IF...THEN statements. [Ref. 7] Each rule will consist of two parts. First is a conditional or IF part that describes a meeting situation which could possibly exist between two vessels. The second part of the rule is a conclusion that is correct, in accordance with CG-169, for the situation described in the conditional part.

As discussed in Chapter II, two separate sets of regulations are included in CG-169. One governs vessels operating in designated international waters and the other governs vessels operating in designated inland waters. Therefore, the rule base must contain rules for both sets of regulations. The rule base will also contain special semantics rules, not taken from CG-169, which will be discussed later.

2. User Interface

Since the Officer of the Deck can not allow his attention to be monopolized by any single function for a period longer than one or two minutes, the user interface must require only a minimal amount of his time, especially for user input to the system. The input format should be short and concise to reduce the time required for entry of data and to reduce the probability of syntactic errors. To provide a robust user interface, the parsing function will be flexible enough to handle slight variations in the user input, as long as it is syntactically correct. Examples of types of data that may be required as input to the system are listed below. Specific data required will vary according to the actual situation.

- time of day
- visibility conditions
- standard lighting patterns observed
- special lighting patterns observed
- dayshapes observed
- true compass bearing of a vessel
- true compass heading of a vessel
- visual aspect of a vessel
- true compass heading of own ship

This data will be referred to collectively as the fact base.

As output, the system will display a recommendation in accordance with CG-169 and a brief description of the rule that was matched by the fact base. This will allow the user to know exactly which conditions the system used as the basis for reaching the recommendation. Also, interpretations of special lighting patterns and dayshapes will be displayed as intermediate conclusions.

3. Inference Engine

The inference engine provides the problem-solving knowledge for the expert system by referencing the rule base and finding the correct rule for the situation as described by the fact base. The matching rule must represent the conditions necessary for reaching a correct conclusion. The conclusion part of the matching rule will be output as a recommendation. This method of establishing the fact base then searching through the rule base until any intermediate conclusions and the final conclusion are found is known as hybrid forward-backward chaining. If no match is found, a message to the user will be displayed that says no match exists and the system has determined that no risk of collision exists.

4. Error Handling

This expert system will detect both syntactic and semantic errors in the user input and handle them in a user-friendly manner. When an error is detected, an error message will be displayed notifying the user of the type of error detected, then the user will be allowed to re-enter the data.

5. Performance Criteria

This system will provide recommendations fast enough to allow the user to utilize the recommendation to assist in avoiding a collision. The response time required to meet this specification will vary with different situations, so a general response-time requirement of ten seconds will be set. Such a response time will be adequate for all but the most unusual of situations.

6. Modes

When vessels are operating in international or inland waters, as specified in CG-169, they must use international or inland rules respectively. Accordingly, this expert system provides separate modes of operation for international and inland situations. The user will choose the appropriate mode at the beginning of a session and that mode will remain in effect for entire session.

C. PROBLEM DECOMPOSITION

1. Basic Expert System Structure

A typical rule-based expert system consists of a rule base, an inference engine, and a user interface. This basic structure will be followed in this thesis. Each of the three main parts of the expert system will be broken into lower-level routines by decomposing the task into separate subtasks.

2. Rule Base Design and Implementation

a. *Writing the Rules*

The first step in the design of the rule base is writing two sets of rules, one for international waters and the other for inland waters. Due to differences in the methods of navigating in international waters and inland waters, and differences in the types of regulations that apply to similar situations, the combination of facts required for writing the two rule sets contains some differences. For international rules, some combination of the following facts is required.

- time of day
- relative bearing of the other vessel
- target angle of the other vessel

- indication of reduced visibility
- indication of special status of the other vessel
- indication of special status of own ship

Inland rules require some combination of the following facts.

- time of day
- type of meeting situation
- indication of reduced visibility
- indication of special status of the other vessel
- indication that other vessel is engaged in special tasking

For both sets, the majority of the rules were determined by hypothetically creating each of the three possible meeting situations then systematically varying the combinations of facts described above. When a combination of facts was set, it was recorded as the conditional part of that rule. Then CG-169 was referenced to provide the conclusion part that was correct for that particular combination of facts. The rules that provide the intermediate conclusions were determined from the definitions of dayshapes and special lighting patterns in CG-169.

b. Symbolic Representation

The two rule sets that resulted from the process described above, although small in comparison to the rule bases found in many expert systems, would require a relatively large amount of storage space in a microcomputer. To overcome that problem, a symbolic representation was developed by encoding each fact as a single character and each conclusion as an integer value. Appendix C and Appendix D contain samples of IF...THEN rules in their coded and decoded formats. The encoded format will also increase the speed at which the inference engine is able to search the rule base, because the comparison of the short character strings is faster than the comparison of entire sentences of fact descriptions.

c. Data Structure

Because the two rule sets developed above are of fixed sizes that will not change during execution of the program, an array of records was chosen as the data structure for the rules. Each record in the array consists of one field for the encoded string of conditions and one field for the encoded conclusion.

d. Partitioning

Separate arrays are used for storing the two rule sets. This partitioning of the rules increases the speed of the searching process that occurs each time the inference engine searches for a match to the fact base. [Ref. 8]

e. Implementation

When the mode, international or inland, is chosen, the appropriate rule set is read into an array from a text file. One of two routines, BUILD_RULES for international rules or BUILD_RULES2 for inland, is called to build the rule base. Appendix C shows the international rules in encoded and decoded form, and Appendix D shows the same for the inland rules.

3. User Interface Design and Implementation

a. Basic Design

The user interface performs the critical tasks of receiving input from the user, creating a fact array, and providing output to the user as dictated by the inference engine. Numbered selections of facts in the form of large menus allow users to input multiple selections with a single entry. This will help to reduce the time required for user interface. Individual requests for data can be made to the user as additional facts are required by the system. The facts entered by the user will be encoded in the same format as the conditional part of the rules in the rule base, so that the inference engine will be able to compare the fact base to the rules. Output is generated from the program in the form of facts from the conditional part and conclusions from the conclusion part. Both of these rule parts are decoded and displayed in a format that presents the conclusion as a recommendation and the conditions as a list of facts that describe the situation as input by the user.

b. User Input Implementation

When the program is executed, the user is prompted for a mode selection, either inland or international. The selected mode will remain in effect until program execution is halted, thus the user will not be required to make a mode selection for each new situation in the session.

Figure 3.1 shows the menu that is displayed when the international mode is selected. From this menu, the user enters all facts concerning the meeting situation that are currently true by entering the appropriate selection numbers separated by commas. For example, an entry that would be made when sighting a vessel at night would be:

- 2,18

International mode requires additional data to completely describe a meeting situation. The user is prompted, one question at a time, for the following data:

- own ship's heading
- other vessel's heading
- other vessel's target angle (during daylight hours only)

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA.

EXAMPLE: 2,6,16

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:RADAR CONTACT.
4. REDUCED VISIBILITY:SOUND SIGNAL HEARD FWD OF BEAM.
5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.

6. RED OVER GREEN.	9. RED OVER WHITE.
7. RED OVER RED.	10. GREEN OVER WHITE.
8. RED OVER WHITE OVER RED.	11. RED OVER RED OVER RED.

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.

12. TWO BLACK BALLS.	14. DOUBLE CONES.
13. BALL DIAMOND BALL.	15. CYLINDER.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.	
17. PORT RUNNING, MASTHEAD, RANGE.	
18. STBD RUNNING, MASTHEAD, RANGE.	
19. STERN.	

Figure 3.1 International Menu.

Figure 3.2 shows the two menus that are displayed in the inland mode. Two menus were necessary because my microcomputer terminal cannot display all of the inland facts on one screen. The selections are made as in the international mode. Selections from the first menu are combined with any selections from the second menu and displayed as one string to show the user the entire entry. All data necessary for inland mode operation is provided by these two menus.

c. Encoding Implementation

The string of input selection numbers separated by commas is parsed into individual numbers. Each number is passed to a CASE statement that maps the number to a code character, then adds the code to the fact base, called FACT FIG in the program.

The same CASE statement simultaneously builds a second code string named MID_RULE. This string is used in semantics checking which will be discussed later.

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA. EXAMPLE: 2,6 . A SECOND MENU WILL DISPLAY ADDITIONAL CONDITIONS WHEN THE ENTER KEY IS PRESSED.

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:FOG SIGNAL HEARD FWD OF BEAM.
4. CONTACT IS A SAILING VESSEL UNDER SAIL.

ONE OF THE FOLLOWING MEETING SITUATIONS EXISTS:

5. CONTACT CROSSING FROM PORT TO STBD.
6. CONTACT CROSSING FROM STBD TO PORT.
7. MEETING CONTACT HEAD TO HEAD.
8. OVERTAKING CONTACT.
9. BEING OVERTAKEN BY CONTACT.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED:

10. PORT AND STBD RUNNING, MASTHEAD, RANGE.
11. PORT RUNNING, MASTHEAD, RANGE.
12. STBD RUNNING, MASTHEAD, RANGE.
13. STERN.

CONTINUE NUMBER SELECTION WITH THE CONDITIONS BELOW. ONLY ONE SELECTION WILL NORMALLY BE MADE FROM THIS MENU, SO NO COMMAS SHOULD BE NEEDED. EXAMPLE: 17

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED:

14. BASKET.
15. TWO ORANGE & WHITE VERTICALLY STRIPED BALLS.
16. DIAMOND, TOP HALF BLACK & WHITE STRIPED, LOWER HALF SOLID RED.
17. BLACK & WHITE STRIPED BALL OVER SOLID RED BALL.
18. TWO BLACK BALLS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS:

20. RED OVER WHITE.
21. WHITE OVER RED OVER RED OVER WHITE.
22. WHITE OVER RED OVER RED.
23. WHITE OVER RED OVER RED OVER RED OVER RED.
24. RED OVER RED OVER RED.
25. ONE WHITE FWD AND ONE WHITE AFT.

Figure 3.2 Inland Menu.

The additional data that is entered separately in the international mode is encoded in a different manner. This data is used to calculate the target angle and relative bearing of an approaching vessel which are in turn used to determine the meeting situation that exists between the two vessels. Although the target angle and relative bearing can each have three hundred sixty different values, the manner in which the three possible meeting situations are defined by CG-169 simplifies encoding

of the values. The three hundred sixty possible values can be divided into four sectors as shown in Figure 3.3. A vessel approaching in sectors A or B indicates a crossing situation, in sector C a head-to-head situation, and in sector D an overtaking situation. Both target angle and relative bearing values are encoded by assigning code characters that correspond to the sectors. These additional characters are also added to FACT FIG.

When navigating in inland waters, the meeting situation can be easily determined visually in normal visibility conditions, because navigation is conducted within marked shipping channels. This means that the additional data required for the international mode is not needed in the inland mode. For restricted visibility conditions, no inland rule exists to cover situations where an approaching vessel is being tracked on radar only, so the additional data is not used then.

d. Program-Output Implementation

When the inference engine finds a rule that matches the fact base, it passes the encoded conclusion to a CASE statement which decodes and displays it. The conditional part of the matched rule is passed to a different CASE statement which decodes it and displays it with the conclusion to allow the user to see the conclusion together with the facts that were used to arrive at the conclusion.

4. Error Checking

Error checking includes syntax, semantics, and range checking. Selection-number strings entered from the menus are checked for proper format, which is a string of numbers separated by commas. Each individual selection number is range-checked to ensure that it is a member of the set of possible selections. The entire group of selection numbers is checked for duplication of selections. Separate routines, CHECK for international mode and CHECK2 for inland mode, check for two selections from certain groupings of selections. Normally only one selection will be true from each of these groupings. An example of such an error would be the selection of two standard lighting configurations from the grouping shown in Figure 3.4. A vessel normally displays only one standard lighting configuration.

The compass-bearing data that is entered in the international mode is range-checked to ensure that the bearing is within the compass-bearing range of 000 to 359 degrees. The target angle bearings entered by the user are compared to those calculated by the program to ensure there is not a difference between the bearings that is significant enough to affect the determination of the correct meeting situation.

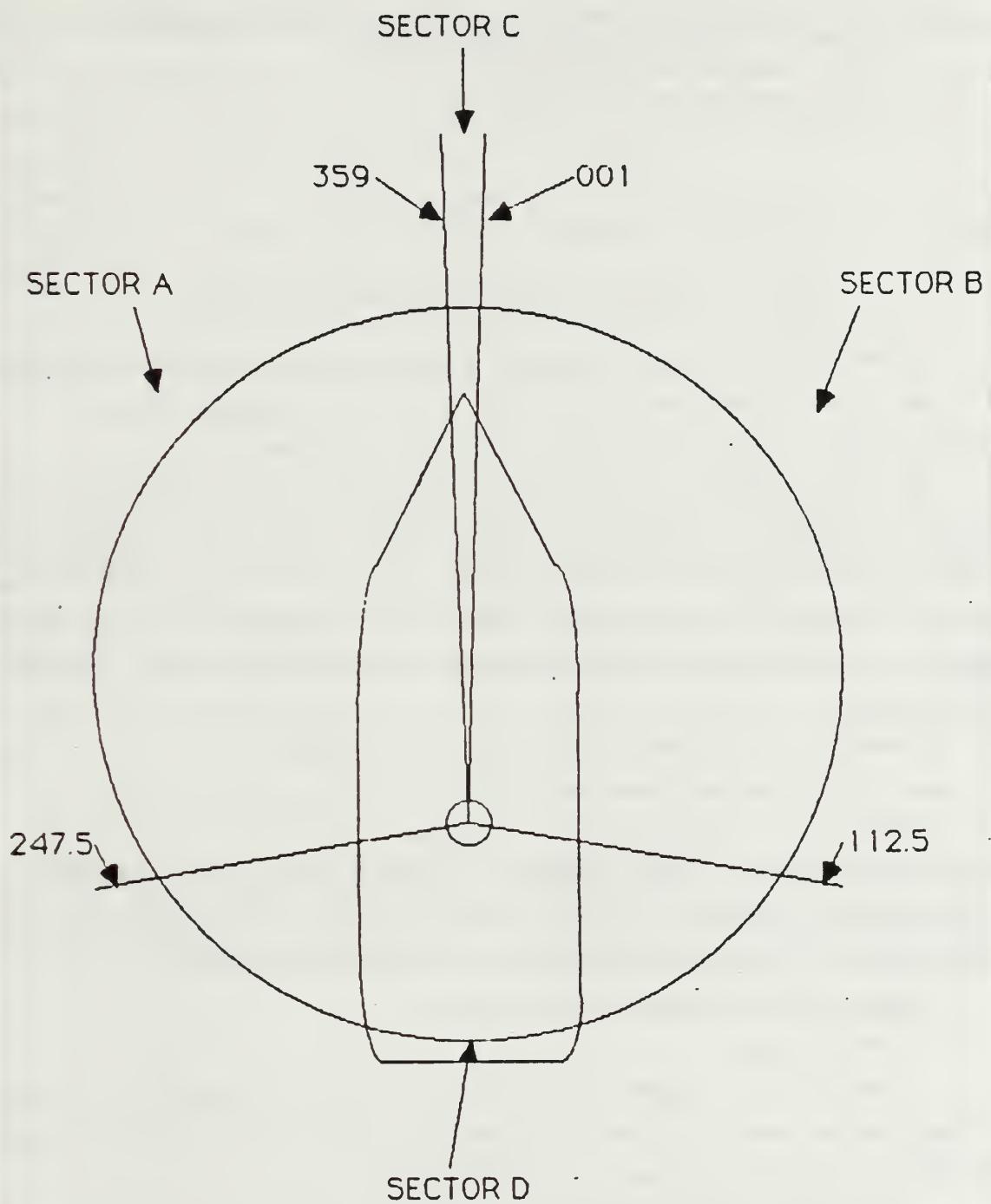


Figure 3.3 Bearing Sectors.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.
17. PORT RUNNING, MASTHEAD, RANGE.
18. STBD RUNNING, MASTHEAD, RANGE.
19. STERN.

Figure 3.4 Standard Lighting Configuration Grouping.

If one of the errors described above is detected, an error message is displayed to the user indicating the type of error, then the program returns to the point where the erroneous data was entered and allows the data to be re-entered.

Semantics checking is performed by the inference engine. The fact string MID_RULE is passed to INFER_ENG and compared to the rule base. In addition to the normal rules, both rule bases contain rules with conditional parts that describe situations which do not normally occur. If MID_RULE matches one of these special semantics rules, the fact base entered by the user is not semantically correct. Examples of such errors are:

- observing any type of lights between sunrise and sunset
- observing dayshapes between sunset and sunrise
- selection of both time periods in one situation

If such an error is detected, an error message is displayed that explains which selections are incompatible and why they do not normally occur together. The program will then return the user to the opening menu and allow the data to be re-entered.

5. Inference Engine Design and Implementation

a. Basic Design

The inference engine will systematically cycle through the rule base comparing the fact base to the rules until a match is found, if one exists. If no match exists, this is an indication that no risk of collision exists.

Since each situation represented in the rule base has only one possible conclusion, no two rules have identical conditional parts. This means that the inference engine must only search the rule base until all matches, intermediate and final, are found. This will prevent needless waste of time spent searching the rule base when a match has already been found.

b. Secondary Tasks

The inference engine will also perform two secondary tasks. The first consists of the interpretation of observed special lighting configurations and dayshapes which are indications that the approaching vessel has a special status. This is accomplished by matching a rule which has as its conditional part the lighting configuration or dayshape and has as its conclusion part the corresponding interpretation. This task is performed when a fact concerning dayshapes or special lighting patterns is entered. The second task consists of checking the user input for semantics errors. The semantics error is detected by matching a rule which has a conclusion part that states why the collection of facts in the conditional part are not compatible. This task is performed after all of the facts have been entered.

c. Implementation

The routine INFER_ENG performs the tasks described above. It steps sequentially through the rule base array by comparing the fact base to the conditional part of each rule until it finds a match or reaches the end of the array without finding a match. The comparison is accomplished by nested FOR loops that sequentially compare each code character in the fact base to all of the code characters in the rule individually. This process provides the flexibility of order independence for the fact base. The order independence means that the selection numbers can be entered in any order.

D. PROGRAM HIERARCHY

Figure 3.5 shows the hierarchy of routines under the main program as implemented in this thesis. The source code listing for the program is contained in Appendix A. Sample sessions of operation in both modes are contained in Appendix B.

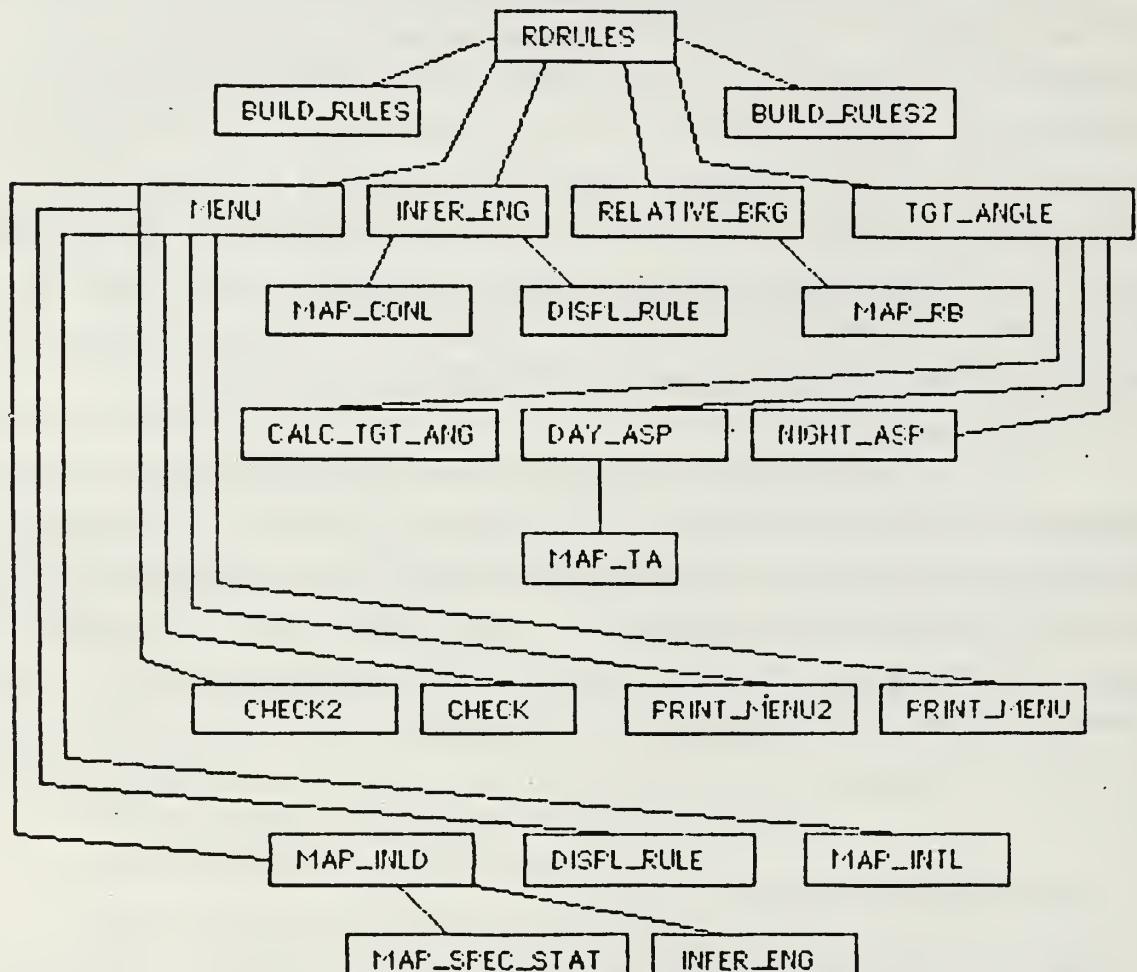


Figure 3.5 Program Hierarchy.

IV. TESTING

A. RESPONSE TIME

One of the main requirements of this expert system is the ability to provide recommendations in timely manner. When the correct maneuvering decision can be made and executed early in a meeting situation, the risk of collision is significantly reduced. To test the response time of this system, fifty test cases were selected. These cases covered a wide range of complexity. At the lower end of the complexity scale was a case that required only two facts to describe the situation. At the upper end of the scale was a case that required the maximum six facts for its description. The complexity of the remaining cases ranged between the two described above. Included were cases that had no match in the rule base which required a search of the entire rule base. The cases were divided evenly between the international and inland modes. Response times ranged from 0.4 to 1.12 seconds with an average response time of 0.73 seconds. The system is clearly able to provide correct recommendations within a satisfactory response time.

B. ACCURACY

It is essential to the operation of this expert system that the meeting type is correctly identified. If the wrong meeting type is calculated by the program, the system's recommendation to the Officer of the Deck could possibly be incorrect for the actual situation. The condition that would most probably result in an incorrect calculation occurs when the relative bearing of an approaching vessel is very near the sector boundaries that were described in Figure 3.3. Test cases were selected with relative bearings one degree on each side of the sector boundaries to ensure that the program could correctly determine the meeting situation.

V. SUMMARY

A. SUCCESSES

The successful implementation of the encoded regulations demonstrated that the answer to the first research question of this thesis is "yes", the regulations in CG-169 can be expressed in a symbolic form that will allow them to be used as a rule base. As discussed in Chapter III and demonstrated in Appendix A, use of the expert system implemented in this thesis is quite simple. The only prior knowledge of the system required is the activation of the program by typing the program name at the computer keyboard. The menu-driven format reduces user input requirements and assumes only a limited knowledge of CG-169 and nautical terminology. This means the system can be quickly integrated into the bridge-watch routine. The response times discussed in Chapter IV show that this expert system can provide prompt recommendations for even the most complicated situations involving risk of collision. And, as discussed in Chapter III, all recommendations provided by this expert system are taken directly from CG-169, and thus are correct for the situation that is entered into the system. Therefore, the answer to the second research question is "yes", the expert system implemented in this thesis provides prompt, correct recommendations to the Officer of the Deck in a user-friendly manner.

By automating the manual procedure of looking into CG-169 for the interpretation of situations that involve risk of collision, this expert system could certainly help to reduce the time required of the Officer of the Deck to make a correct maneuvering decision and reduces the probability of error in making the correct decision. Removing the manual "look-up" procedure also frees the Officer of the Deck to more closely monitor the operation of the bridge watch team during the critical function of preventing collisions at sea.

The robust nature of this expert system combined with the explanatory error-response messages create an excellent teaching tool for Officer of the Deck trainees. Pre-written sessions could be constructed to provide training for various situations that involve risk of collision. This training function could be used by bridge watch teams while underway or as part of inport Officer of the Deck training.

Implementation of this expert system for shipboard use would be relatively inexpensive in terms of cost and quite flexible in terms of hardware selection. The compiled program in a .COM file and additional rule base files require only thirty-six kilobytes of memory, therefore almost any small microcomputer could run the program. The program is written in Turbo Pascal which is available for both CP/M and DOS operating systems, providing a very wide market of microcomputers from which to choose. With the increased presence of microcomputers onboard Naval ships, the system could even be implemented with existing computer resources.

Some Officers of the Deck do rely on their memorization of CG-169 for making maneuvering decisions, but this practice is not commonly supported by commanding officers. Since output from this system is derived directly from CG-169, recommendations from this system can serve to lower the probability of error that exists when an Officer of the Deck relies too heavily on his or her memorization of CG-169. Although this probability is not significant as it exists now, this system might help to prevent a disaster that could result from the infrequent error.

B. LIMITATIONS

Although this expert system can provide prompt, correct recommendations, it is not a real-time system, and thus it views every situation with no sense of timing. A certain risk of collision situation may require twenty-five minutes for the actual closest point of approach between the vessels to occur due to a slow closure rate. However, the same situation might require only ten minutes to reach the closest point of approach if the closure rate is very fast. Although there would be no difference between the recommendations given in the two cases above, it would be an added advantage if the recommendation could also take into consideration the specific time related issues involved in making a maneuvering decision.

To effect the extension of this system to provide real-time recommendations, a system clock would be required in the computer system being used, and modifications to the actual expert system program would be required to allow the input of changes in the bearing and range of the other vessel. The extension of this expert system to become a real-time system could enhance its value to the Officer of the Deck.

The recommendations provided by this expert system are of a very general nature, and must be recognized as such. This system does not consider the tactical situation, other shipping in the vicinity that is not involved in the current meeting

situation, or concern for navigational hazards that could be present. System users must take into consideration these other factors before making a final decision.

Although the time required for data entry into this system is short, it does require the user to shift their attention from the actions of the approaching vessel. To shorten the data-entry time even more, a direct data entry from the radar equipment could be used. However, visually acquired data, such as observation of dayshapes and lighting patterns, would require manual entry.

APPENDIX A SOURCE CODE LISTING

```
PROGRAM RDRULES;

CONST
  MAX_INTL_RULE = 157;
  MAX_INLD_RULE = 105;

TYPE
  INPUT_STR = STRING[12];
  CODE_INT = 0..30;
  SHRT_STR = STRING[3];
  RULE_STR = STRING[10];
  RULE_REC = RECORD
    CONL:CODE_INT;
    RULE FIG:RULE_STR
  END;
  INTL_RULE_ARRAY = ARRAY[1..MAX_INTL_RULE] OF RULE_REC;
  INLD_RULE_ARRAY = ARRAY[1..MAX_INLD_RULE] OF RULE_REC;
  SHORT_INT = 1..2;
  SELECT_ARRAY = ARRAY[1..7] OF INTEGER;

VAR
  SETTING,LTGCODE,TIME,FOG,FOG2,DSHAPE,SPEC_LTS,RUN_LTS,
  MID_SIZE,MAX_FAX,TIME1,TIME2:CODE_INT;
  MID_RULE,FACT FIG:RULE_STR;
  INTL_RULES:INTL_RULE_ARRAY;
  INLD_RULES:INLD_RULE_ARRAY;
  FILEVAR:TEXT;
  RULE_SET,LOW_VIS:SHORT_INT;
  GOOD,FOG_SIG_CONTACT,CONTINUE,FOUND,QUIT:BOOLEAN;
  ANS:CHAR;
  CONTACT_TRUE_BRG:SHRT_STR;

PROCEDURE MAP_CONL(CODE:CODE_INT);
BEGIN
  CASE CODE OF
    1:WRITELN(' YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.');
    2:BEGIN
      WRITELN(' CONTACT HAS SPECIAL STATUS. YOU ARE GIVE-WAY VESSEL.');
      WRITELN(' MANEUVER TO AVOID CONTACT. TURN STBD IF POSSIBLE.');
      IF (TIME = 1) THEN
        WRITELN(' SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.')
      ELSE
        WRITELN(' SHOW ONE LIGHT FLASH TO SIGNAL A STBD TURN.')
    END;
    3:BEGIN
      WRITELN(' YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.');
      WRITELN(' TURN STBD IF POSSIBLE.');
      IF (RULE_SET = 1) THEN
        IF (TIME = 1) THEN
          WRITELN(' SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.')
        ELSE
          WRITELN(' SHOW ONE LIGHT FLASH TO SIGNAL A STBD TURN.')
      END;
    4:BEGIN
      WRITELN(' OWN SHIP HAS SPECIAL STATUS. YOU ARE STAND-ON VESSEL.');
      WRITELN(' MAINTAIN COURSE AND SPEED.')
    END;
    5:BEGIN
```

```

WRITELN(' BOTH SHIPS MUST GIVE WAY. ALTER COURSE TO STBD TO');
WRITELN(' AVOID CONTACT.');
IF (TIME = 1) THEN
  WRITELN(' SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.')
ELSE
  WRITELN(' SHOW ONE LIGHT FLASH TO SIGNAL A STBD TURN.')
END;
6:BEGIN
  FACT FIG := FACT FIG + 'z';
  MAX_FAX := MAX_FAX + 1
END;
7:BEGIN
  WRITELN;
  WRITELN(' REDUCE SPEED TO BARE STEERAGE-WAY. PROCEED WITH EXTREME');
  WRITELN(' CAUTION UNTIL THE DANGER OF COLLISION IS OVER.');
  WRITELN;
END;
8:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',TIME,' AND ',SPEC_LTS,' ARE NOT COMPATIBLE.');
  WRITELN('LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
9:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',TIME,' AND ',RUN_LTS,' ARE NOT COMPATIBLE.');
  WRITELN('LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
10:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',TIME,' AND ',SPEC_LTS,' AND ',RUN_LTS);
  WRITELN('ARE NOT COMPATIBLE. LIGHTS OF ANY TYPE ARE NOT NORMALLY');
  WRITELN('DISPLAYED AFTER SUNRISE.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
11:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',TIME,' AND ',DSHAPE,' ARE NOT COMPATIBLE.');
  WRITELN('DAYSHAPES ARE NOT NORMALLY DISPLAYED AFTER SUNSET.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
12:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',DSHAPE);
  IF (LOW_VIS = 2) THEN
    WRITELN(' AND ',FOG,' ARE NOT COMPATIBLE.')
  ELSE
    WRITELN(' AND ',FOG2,' ARE NOT COMPATIBLE.');
  WRITELN('DAYSHAPES CAN NOT NORMALLY BE SEEN DURING REDUCED');
  WRITELN('VISIBILITY CONDITIONS.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
13:BEGIN

```

```

CONTINUE := FALSE;
WRITELN;
WRITELN('SEMANTIC ERROR.');
WRITE('SELECTIONS ',SPEC_LTS);
IF (LOW_VIS = 2) THEN
  WRITELN(' AND ',FOG,' ARE NOT COMPATIBLE.')
ELSE
  WRITELN(' AND ',FOG2,' ARE NOT COMPATIBLE.');
WRITELN('LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED');
WRITELN('VISIBILITY CONDITIONS.');
WRITELN('RE-ENTER SELECTION NUMBERS.');
WRITELN
END;
14:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITE('SELECTIONS ',RUN_LTS);
  IF (LOW_VIS = 2) THEN
    WRITELN(' AND ',FOG,' ARE NOT COMPATIBLE.')
  ELSE
    WRITELN(' AND ',FOG2,' ARE NOT COMPATIBLE.');
  WRITELN('LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED');
  WRITELN('VISIBILITY CONDITIONS.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
15:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITE('SELECTIONS ',RUN_LTS,' AND ',SPEC_LTS);
  IF (LOW_VIS = 2) THEN
    WRITELN(' AND ',FOG,' ARE NOT COMPATIBLE.')
  ELSE
    WRITELN(' AND ',FOG2,' ARE NOT COMPATIBLE.');
  WRITELN('LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED');
  WRITELN('VISIBILITY CONDITIONS.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
16:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTION ',TIME2,' REQUIRES ANOTHER SELECTION SUCH AS A');
  WRITELN('LIGHTING PATTERN OR REDUCED VISIBILITY CONDITION BEFORE THE');
  WRITELN('SITUATION CAN BE ANALYZED.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
17:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTION ',SPEC_LTS,' ALSO REQUIRES A STANDARD');
  WRITELN('LIGHTING PATTERN. SPECIAL LIGHTING PATTERNS ARE NOT');
  WRITELN('NORMALLY DISPLAYED WITHOUT A STANDARD LIGHTING PATTERN.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
18:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',FOG,' AND ',FOG2,' ARE NOT COMPATIBLE.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;

```

```

19:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',TIME1,' AND ',TIME2,' ARE NOT COMPATIBLE.');
  WRITELN('THE TWO POSSIBLE TIME-PERIODS CAN NOT OCCUR TOGETHER.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
20:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',DSHAPE,' AND ',RUN_LTS,' AND ',FOG2);
  WRITELN('ARE NOT COMPATIBLE. LIGHTS OR DAYSHAPES CAN NOT');
  WRITELN('NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
21:BEGIN
  CONTINUE := FALSE;
  WRITELN;
  WRITELN('SEMANTIC ERROR.');
  WRITELN('SELECTIONS ',DSHAPE,' AND ',FOG2,' AND ',SPEC_LTS,' AND');
  WRITELN('RUN_LTS ARE NOT COMPATIBLE. LIGHTS OR DAYSHAPES CAN NOT');
  WRITELN('NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.');
  WRITELN('RE-ENTER SELECTION NUMBERS.');
  WRITELN
END;
22:BEGIN
  WRITELN(' BOTH SHIPS MUST GIVE WAY. GIVE ONE SHORT BLAST TO SIGNAL');
  WRITELN(' YOUR INTENTION TO ALTER COURSE TO STBD OR ANSWER THE ');
  WRITELN(' CONTACT''S SIGNAL WITH THE SAME SIGNAL. DO NOT ALTER COURSE');
  WRITELN(' UNTIL YOU AND THE CONTACT HAVE MATCHED SIGNALS.')
END;
23:BEGIN
  WRITELN(' YOU ARE GIVE-WAY VESSEL. SOUND ONE SHORT BLAST IF YOU');
  WRITELN(' INTEND TO OVERTAKE ON THE STBD SIDE OR TWO SHORT BLASTS IF');
  WRITELN(' YOU INTEND TO OVERTAKE ON THE PORT SIDE. WAIT FOR ');
  WRITELN(' THE SAME SIGNAL IN AGREEMENT BEFORE OVERTAKING. IF THE');
  WRITELN(' CONTACT ANSWERS WITH THE DANGER SIGNAL, FOUR OR MORE SHORT');
  WRITELN(' BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO OVERTAKE THE');
  WRITELN(' CONTACT.')
END;
24:BEGIN
  WRITELN(' YOU MUST KEEP OUT OF THE WAY OF SAILING VESSELS UNLESS YOU');
  WRITELN(' ARE CONSTRAINED BY A NARROW CHANNEL. IF YOU ARE CONSTRAINED');
  WRITELN(' AND A CLOSE QUARTER SITUATION IS EMINENT, SOUND THE DANGER');
  WRITELN(' SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION.')
END;
25:BEGIN
  WRITELN(' REDUCE SPEED TO ENSURE SAFETY OF BOTH VESSELS. WHEN PASSING');
  WRITELN(' WITHIN 200 FT. OF CONTACT, REDUCE SPEED TO 5 MPH OR LESS.')
END;
26:BEGIN
  WRITELN(' WHEN WITHIN ONE MILE OF CONTACT, INDICATE INTENTION TO PASS');
  WRITELN(' WITH ONE LONG BLAST. CONTACT WILL DIRECT YOU TO PROPER SIDE');
  WRITELN(' FOR PASSAGE WITH ONE SHORT BLAST FOR A STBD PASSAGE OR TWO');
  WRITELN(' SHORT BLASTS FOR A PORT PASSAGE. ANSWER WITH SAME SIGNAL TO');
  WRITELN(' ACKNOWLEDGE. IF CONTACT SOUNDS DANGER SIGNAL, FOUR OR MORE');
  WRITELN(' SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO PASS.');
  WRITELN(' SLOW DOWN OR STOP AND AWAIT FURTHER SIGNAL.')
END;
27:BEGIN
  WRITELN(' YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.');
  WRITELN(' ANSWER PASSING VESSEL''S INDICATION OF DESIRED SIDE TO PASS');
  WRITELN(' WITH SAME SIGNAL IF IT IS SAFE, BUT ANSWER WITH THE DANGER');
  WRITELN(' SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, IF ');
  WRITELN(' THERE IS A DANGER.')

```

```
END;
28:WRITELN(' MANEUVER TO AVOID A VESSEL AT ANCHOR. ');
END END;
```

```
PROCEDURE MAP_TA (VAR QUADRANT:CHAR;BEARING:INTEGER);

BEGIN
  IF (BEARING>=1) AND (BEARING<=112) THEN
    QUADRANT := 'c'
  ELSE IF (BEARING>=113) AND (BEARING<=247) THEN
    QUADRANT := 'd'
  ELSE IF (BEARING>=248) AND (BEARING<=359) THEN
    QUADRANT := 'e'
  ELSE
    QUADRANT := 'f' END;
```

```
PROCEDURE MAP_RB (VAR QUADRANT:CHAR;BEARING:INTEGER);

BEGIN
  IF (BEARING>=1) AND (BEARING<=112) THEN
    QUADRANT := 'g'
  ELSE IF (BEARING>=113) AND (BEARING<=247) THEN
    QUADRANT := 'h'
  ELSE IF (BEARING>=248) AND (BEARING<=359) THEN
    QUADRANT := 'i'
  ELSE
    QUADRANT := 'j' END;
```

```
PROCEDURE CALC_TGT_ANG (VAR TA:SHRT_STR;HTB,HSH:SHRT_STR);

VAR
  CODE,TA_INT,YTB_INT,HSH_INT,HTB_INT:INTEGER;

BEGIN
  VAL(HTB,HTB_INT,CODE);
  VAL(HSH,HSH_INT,CODE);
  YTB_INT := HTB_INT-180;
  IF YTB_INT < 0 THEN
    YTB_INT := YTB_INT + 360;
  TA_INT := YTB_INT - HSH_INT;
  IF TA_INT < 0 THEN
    TA_INT := TA_INT + 360;
  IF (TA_INT < 100) AND (TA_INT > 9) THEN BEGIN
    STR(TA_INT,TA);
    TA := '0' + TA;
    END
  ELSE IF (TA_INT >= 0) AND (TA_INT <= 9) THEN BEGIN
    STR(TA_INT,TA);
    TA := '00' + TA;
    END
  ELSE
    STR(TA_INT,TA) END;
```

```
PROCEDURE BUILD_RULES2;

VAR
  J:INTEGER;
```

```

BEGIN
  ASSIGN(FILEVAR,'YRULES.TXT');
  RESET(FILEVAR);
  FOR J := 1 TO MAX_INLD_RULE DO
    WITH INLD_RULES[J] DO BEGIN
      READLN(FILEVAR,RULE FIG);
      READLN(FILEVAR,CONL)
    END;
  CLOSE(FILEVAR) END;

PROCEDURE BUILD_RULES;
VAR
  J:INTEGER;
BEGIN
  ASSIGN(FILEVAR,'XRULES.TXT');
  RESET(FILEVAR);
  FOR J := 1 TO MAX_INTL_RULE DO
    WITH INTL_RULES[J] DO BEGIN
      READLN(FILEVAR,RULE FIG);
      READLN(FILEVAR,CONL)
    END;
  CLOSE(FILEVAR) END;

PROCEDURE NIGHT_ASPECT (VAR FINI:BOOLEAN;BEARING:INTEGER;TA:SHRT_STR);
TYPE
  STRG = STRING[9]; VAR
  NOT_MATCH:BOOLEAN;
  LGT_QUAD:STRG;

BEGIN
  NOT_MATCH := FALSE;
  CASE LTGCODE OF
    16:BEGIN
      IF (BEARING = 0) THEN BEGIN
        FINI := TRUE;
        FACT FIG := FACT FIG + 'f';
        MAX_FAX := MAX_FAX + 1;
      END
      ELSE BEGIN
        LGT_QUAD := '000.';
        NOT_MATCH := TRUE;
      END
    END;
    17:BEGIN
      IF(BEARING>=248) AND (BEARING<=359) THEN BEGIN
        FINI := TRUE;
        FACT FIG := FACT FIG + 'e';
        MAX_FAX := MAX_FAX + 1;
      END
      ELSE BEGIN
        LGT_QUAD := 'PORT FWD.';
        NOT_MATCH := TRUE;
      END
    END;
    18:BEGIN
      IF (BEARING>=1) AND (BEARING<=112) THEN BEGIN
        FINI := TRUE;
        FACT FIG := FACT FIG + 'c';
        MAX_FAX := MAX_FAX +1;
      END
      ELSE BEGIN

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        LGT_QUAD := 'STBD FWD.';
        NOT_MATCH := TRUE;
    END;
END;
19:BEGIN
    IF (BEARING>=113) AND (BEARING<=247) THEN BEGIN
        FINI := TRUE;
        FACT FIG := FACT FIG + 'd';
        MAX_FAX := MAX_FAX +1;
        END
    ELSE BEGIN
        LGT_QUAD := 'AFT. ';
        NOT_MATCH := TRUE
    END;
END;
END;
IF NOT_MATCH THEN BEGIN
    WRITELN;
    WRITELN('PROGRAM-COMPUTED TARGET ANGLE DOES NOT MATCH THE ASPECT');
    WRITELN('DETERMINED BY LIGHT CONFIGURATION. PROGRAM-COMPUTED TARGET');
    WRITELN('ANGLE IS ',TA,'. TARGET ANGLE INDICATED BY LIGHTING IS');
    WRITELN(LGT_QUAD,' RE-CHECK MANEUVERING BOARD SOLUTION AND');
    WRITELN('RUNNING LIGHT CONFIGURATION.');
    WRITELN;
END END;

```

```

PROCEDURE CHECK (INPUT_ARRAY:SELECT_ARRAY;H:INTEGER;VAR OKAY:BOOLEAN);

VAR
    D,E,P,Q:INTEGER;
    TIME_OK,DUPED,SAME_GROUP1,SAME_GROUP2,SAME_GROUP3:BOOLEAN;

BEGIN
    TIME_OK := FALSE;
    DUPED := FALSE;
    SAME_GROUP1 := FALSE;
    SAME_GROUP2 := FALSE;
    SAME_GROUP3 := FALSE;
    FOR D := 1 TO H-1 DO
        IF (INPUT_ARRAY[D] = 1) OR (INPUT_ARRAY[D] = 2) THEN
            TIME_OK := TRUE;
    IF NOT TIME_OK THEN BEGIN
        OKAY:= FALSE;
        WRITELN('NO TIME PERIOD WAS ENTERED. A TIME PERIOD MUST BE ENTERED');
        WRITELN('BEFORE A SITUATION CAN BE ANALYZED.');
        WRITELN('RE-ENTER SELECTION NUMBERS.');
        WRITELN('TO CONTINUE, PRESS ANY KEY.');
        WHILE NOT KEYPRESSED DO
            DELAY(1);
        WRITELN;WRITELN
    END;
    FOR D := 1 TO H-2 DO
        FOR E := D+1 TO H-1 DO
            IF (INPUT_ARRAY[D] = INPUT_ARRAY[E]) THEN BEGIN
                OKAY := FALSE;
                P := D;
                DUPED := TRUE
            END;
    IF DUPED THEN BEGIN
        WRITELN('SELECTION ',INPUT_ARRAY[P],' IS DUPLICATED.');
        WRITELN('RE-ENTER SELECTION NUMBERS.');
        WRITELN('TO CONTINUE, PRESS ANY KEY.');
        WHILE NOT KEYPRESSED DO
            DELAY(1);
        WRITELN;WRITELN
    END;
    FOR D := 1 TO H-2 DO
        FOR E := D+1 TO H-1 DO

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```

IF ((INPUT_ARRAY[D] IN [12,13,14,15]) AND (INPUT_ARRAY[E] IN
[12,13,14,15])) THEN BEGIN
    OKAY := FALSE;
    P := D;
    Q := E;
    SAME_GROUP1 := TRUE
  END;
IF SAME_GROUP1 THEN BEGIN
  WRITELN('SELECTIONS ',INPUT_ARRAY[P],' AND ',INPUT_ARRAY[Q],' CAN NOT');
  WRITELN('BE SELECTED TOGETHER BECAUSE TWO DIFFERENT DAYSHAPES WILL NOT ');
  WRITELN('BE SEEN ON THE SAME SHIP. RE-ENTER SELECTION NUMBERS.');
  WRITELN('TO CONTINUE, PRESS ANY KEY.');
  WHILE NOT KEYPRESSED DO
    DELAY(1);
  WRITELN;WRITELN
END;
FOR D := 1 TO H-2 DO
  FOR E := D+1 TO H-1 DO
    IF ((INPUT_ARRAY[D] IN [6,7,8,9,10,11]) AND (INPUT_ARRAY[E] IN
[6,7,8,9,10,11])) THEN BEGIN
      OKAY := FALSE;
      P := D;
      Q := E;
      SAME_GROUP2 := TRUE
    END;
IF SAME_GROUP2 THEN BEGIN
  WRITELN('SELECTIONS ',INPUT_ARRAY[P],' AND ',INPUT_ARRAY[Q],' CAN NOT');
  WRITELN('BE SELECTED TOGETHER BECAUSE TWO DIFFERENT SPECIAL LIGHTING');
  WRITELN('PATTERNS WILL NOT BE SEEN ON THE SAME SHIP. RE-ENTER SELECTION');
  WRITELN('NUMBERS.');
  WRITELN('TO CONTINUE, PRESS ANY KEY.');
  WHILE NOT KEYPRESSED DO
    DELAY(1);
  WRITELN;WRITELN
END;
FOR D := 1 TO H-2 DO
  FOR E := D+1 TO H-1 DO
    IF ((INPUT_ARRAY[D] IN [16,17,18,19]) AND (INPUT_ARRAY[E] IN
[16,17,18,19])) THEN BEGIN
      OKAY := FALSE;
      P := D;
      Q := E;
      SAME_GROUP3 := TRUE
    END;
IF SAME_GROUP3 THEN BEGIN
  WRITELN('SELECTIONS ',INPUT_ARRAY[P],' AND ',INPUT_ARRAY[Q],' CAN NOT');
  WRITELN('BE SELECTED TOGETHER BECAUSE TWO DIFFERENT STANDARD LIGHTING');
  WRITELN('PATTERNS WILL NOT BE SEEN ON THE SAME SHIP. RE-ENTER SELECTION');
  WRITELN('NUMBERS.');
  WRITELN('TO CONTINUE, PRESS ANY KEY.');
  WHILE NOT KEYPRESSED DO
    DELAY(1);
  WRITELN;WRITELN;
END END;

```

```

PROCEDURE PRINT_MENU2(VAR LONGCODE:INPUT_STR);

VAR
  FIRSTCODE,SNDCODE:RULE_STR;
  LEN,G:INTEGER;

BEGIN
  WRITELN('ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING');
  WRITELN('CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED');
  WRITELN('BY A COMMA. EXAMPLE: 2,6 . A SECOND MENU WILL DISPLAY ADDITIONAL');
  WRITELN('CONDITIONS WHEN THE ENTER KEY IS PRESSED.');
  WRITELN(' 1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.');
  WRITELN(' 2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.');

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WRITELN(' 3. REDUCED VISIBILITY:FOG SIGNAL HEARD FWD OF BEAM.');
WRITELN(' 4. CONTACT IS A SAILING VESSEL UNDER SAIL.');
WRITELN('ONE OF THE FOLLOWING MEETING SITUATIONS EXISTS:');
WRITELN(' 5. CONTACT CROSSING FROM PORT TO STBD.');
WRITELN(' 6. CONTACT CROSSING FROM STBD TO PORT.');
WRITELN(' 7. MEETING CONTACT HEAD TO HEAD.');
WRITELN(' 8. OVERTAKING CONTACT.      9. BEING OVERTAKEN BY CONTACT.');
WRITELN('ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED:');
WRITELN(' 10. PORT AND STBD RUNNING,MASTHEAD,RANGE.');
WRITELN(' 11. PORT RUNNING,MASTHEAD,RANGE.');
WRITELN(' 12. STBD RUNNING,MASTHEAD,RANGE.');
WRITELN(' 13. STERN.);WRITELN;
READLNI(FIRSTCODE);
WRITELN(FIRSTCODE);
LEN := LENGTH(FIRSTCODE);
FOR G := 1 TO LEN DO
  WHILE (FIRSTCODE[G] = ' ') AND (LENGTH(FIRSTCODE) >= 1) DO
    DELETE(FIRSTCODE,G,1);
LEN := LENGTH(FIRSTCODE);
IF (FIRSTCODE[LEN] <> ',') THEN
  FIRSTCODE := FIRSTCODE + ',';
CLRSCR;
WRITELN('CONTINUE NUMBER SELECTION WITH THE CONDITIONS BELOW. ONLY ONE');
WRITELN('SELECTION WILL NORMALLY BE MADE FROM THIS MENU, SO NO COMMAS');
WRITELN('SHOULD BE NEEDED. EXAMPLE: 17 ');WRITELN;
WRITELN('ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED:');
WRITELN(' 14. BASKET.          19. ONE BLACK BALL.');
WRITELN(' 15. TWO ORANGE & WHITE VERTICALLY STRIPED BALLS.');
WRITELN(' 16. DIAMOND, TOP HALF BLACK & WHITE STRIPED, LOWER HALF SOLID RED.');
WRITELN(' 17. BLACK & WHITE STRIPED BALL OVER SOLID RED BALL.');
WRITELN(' 18. TWO BLACK BALLS.');
WRITELN('ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS:');
WRITELN(' 20. RED OVER WHITE.      26. RED OVER RED.');
WRITELN(' 21. WHITE OVER RED OVER RED OVER WHITE.');
WRITELN(' 22. WHITE OVER RED OVER RED.');
WRITELN(' 23. WHITE OVER RED OVER RED OVER RED OVER RED.');
WRITELN(' 24. RED OVER RED OVER RED.');
WRITELN(' 25. ONE WHITE FWD AND ONE WHITE AFT.');
READLNI(SNDCODE);
WRITELN(SNDCODE);
LONGCODE := FIRSTCODE + SNDCODE;
LEN := LENGTH(LONGCODE);
FOR G := 1 TO LEN DO
  WHILE (LONGCODE[G] = ' ') AND (LENGTH(LONGCODE) >= 1) DO
    DELETE(LONGCODE,G,1);
LEN := LENGTH(LONGCODE);
IF (LONGCODE[LEN] = ',') THEN
  DELETE(LONGCODE,LEN,1);
WRITELN('THE COMPLETE SELECTION FOR THIS INLAND SITUATION IS ',LONGCODE); END;

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PROCEDURE PRINT_MENU;

BEGIN

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WRITELN('ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING');
WRITELN('CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED');
WRITELN('BY A COMMA.');
WRITELN('EXAMPLE: 2,6,16 ');
WRITELN(' 1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.');
WRITELN(' 2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.');
WRITELN(' 3. REDUCED VISIBILITY:RADAR CONTACT.');
WRITELN(' 4. REDUCED VISIBILITY:SOUND SIGNAL HEARD FWD OF BEAM.');
WRITELN(' 5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.');
WRITELN('ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.');
WRITELN(' 6. RED OVER GREEN.      9. RED OVER WHITE.');
WRITELN(' 7. RED OVER RED.        10. GREEN OVER WHITE.');
WRITELN(' 8. RED OVER WHITE OVER RED. 11. RED OVER RED OVER RED.');
WRITELN('ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.');
WRITELN(' 12. TWO BLACK BALLS.    14. DOUBLE CONES.');

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WRITELN(' 13. BALL DIAMOND BALL.           15. CYLINDER. ');
WRITELN('ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.');
WRITELN(' 16. PORT AND STBD RUNNING,MASTHEAD,RANGE.');
WRITELN(' 17. PORT RUNNING,MASTHEAD,RANGE.');
WRITELN(' 18. STBD RUNNING,MASTHEAD,RANGE.');
WRITELN(' 19. STERN.') END;

PROCEDURE MAP_INLAND (CODE:INTEGER;VAR SHORT_RULE:RULE_STR);

BEGIN
  CASE CODE OF
    1:BEGIN
      MID_RULE := MID_RULE + 'a';
      MID_SIZE := MID_SIZE + 1;
      TIME := 1;
      TIME1 := 1;
      FACT FIG := FACT FIG + 'a';
      MAX_FAX := MAX_FAX + 1
    END;
    2:BEGIN
      MID_RULE := MID_RULE + ' ';
      MID_SIZE := MID_SIZE + 1;
      TIME := 2;
      TIME2 := 2;
      FACT FIG := FACT FIG + 'b';
      MAX_FAX := MAX_FAX + 1
    END;
    3:BEGIN
      FOG2 := CODE;
      FOG_SIG_CONTACT := TRUE;
      FACT FIG := FACT FIG + '*';
      MAX_FAX := MAX_FAX + 1;
      MID_RULE := MID_RULE + 's';
      MID_SIZE := MID_SIZE + 1
    END;
    4:BEGIN
      MID_RULE := MID_RULE + 'A';
      MID_SIZE := MID_SIZE + 1;
      FACT FIG := FACT FIG + 'A';
      MAX_FAX := MAX_FAX + 1
    END;
    5:BEGIN
      FACT FIG := FACT FIG + 'B';
      MAX_FAX := MAX_FAX + 1
    END;
    6:BEGIN
      FACT FIG := FACT FIG + 'C';
      MAX_FAX := MAX_FAX + 1
    END;
    7:BEGIN
      FACT FIG := FACT FIG + 'D';
      MAX_FAX := MAX_FAX + 1
    END;
    8:BEGIN
      FACT FIG := FACT FIG + 'E';
      MAX_FAX := MAX_FAX + 1
    END;
    9:BEGIN
      FACT FIG := FACT FIG + 'F';
      MAX_FAX := MAX_FAX + 1
    END;
    10:BEGIN
      FACT FIG := FACT FIG + 'G';
      MAX_FAX := MAX_FAX + 1
    END;
    11:BEGIN
      FACT FIG := FACT FIG + 'H';
    END;
  END;
END;

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    MAX_FAX := MAX_FAX + 1
  END;
12:BEGIN
    FACT FIG := FACT FIG + 'I';
    MAX_FAX := MAX_FAX + 1
  END;
13:BEGIN
    FACT FIG := FACT FIG + 'J';
    MAX_FAX := MAX_FAX + 1
  END;
14:BEGIN
    SHORT_RULE := 'K';
    FACT FIG := FACT FIG + 'K';
    MAX_FAX := MAX_FAX + 1
  END;
15:BEGIN
    SHORT_RULE := 'L';
    FACT FIG := FACT FIG + 'L';
    MAX_FAX := MAX_FAX + 1
  END;
16:BEGIN
    SHORT_RULE := 'M';
    FACT FIG := FACT FIG + 'M';
    MAX_FAX := MAX_FAX + 1
  END;
17:BEGIN
    SHORT_RULE := 'N';
    FACT FIG := FACT FIG + 'N';
    MAX_FAX := MAX_FAX + 1
  END;
18:BEGIN
    SHORT_RULE := 'O';
    FACT FIG := FACT FIG + 'O';
    MAX_FAX := MAX_FAX + 1
  END;
19:BEGIN
    SHORT_RULE := 'P';
    FACT FIG := FACT FIG + 'P';
    MAX_FAX := MAX_FAX + 1
  END;
20:BEGIN
    SHORT_RULE := 'Q';
    FACT FIG := FACT FIG + 'Q';
    MAX_FAX := MAX_FAX + 1
  END;
21:BEGIN
    SHORT_RULE := 'R';
    FACT FIG := FACT FIG + 'R';
    MAX_FAX := MAX_FAX + 1
  END;
22:BEGIN
    SHORT_RULE := 'S';
    FACT FIG := FACT FIG + 'S';
    MAX_FAX := MAX_FAX + 1
  END;
23:BEGIN
    SHORT_RULE := 'T';
    FACT FIG := FACT FIG + 'T';
    MAX_FAX := MAX_FAX + 1
  END;
24:BEGIN
    SHORT_RULE := 'U';
    FACT FIG := FACT FIG + 'U';
    MAX_FAX := MAX_FAX + 1
  END;
25:BEGIN
    SHORT_RULE := 'V';
    FACT FIG := FACT FIG + 'V';
    MAX_FAX := MAX_FAX + 1
  END;

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        END;
26:BEGIN
        SHORT_RULE := 'W';
        FACT FIG := FACT FIG + 'W';
        MAX_FAX := MAX_FAX + 1
    END;
END;
IF CODE IN [10,11,12,13] THEN BEGIN
    RUN_LTS := CODE;
    MID_RULE := MID_RULE + '!';
    MID_SIZE := MID_SIZE + 1;
    END
ELSE IF CODE IN [14,15,16,17,18,19] THEN BEGIN
    DSHAPE := CODE;
    MID_RULE := MID_RULE + '&';
    MID_SIZE := MID_SIZE + 1;
    WRITELN('INTERPRETATION OF DAYSHAPE IS:');
    END
ELSE IF CODE IN [20,21,22,23,24,25,26] THEN BEGIN
    SPEC_LTS := CODE;
    MID_RULE := MID_RULE + '?';
    MID_SIZE := MID_SIZE + 1;
    WRITELN('INTERPRETATION OF SPECIAL LIGHTS IS:');
END END;

PROCEDURE DISPL_RULE(RULE:RULE_STR;RULE_LEN:INTEGER;SETTING:CODE_INT);
VAR
    I:INTEGER;
BEGIN
    FOR I := 1 TO RULE_LEN DO
        CASE RULE[I] OF
            'a':WRITELN(' TIME = DAY.');
            'b':WRITELN(' TIME = NIGHT.');
            'c':WRITELN(' TARGET ANGLE IS STBD FWD.');
            'd':WRITELN(' TARGET ANGLE IS AFT.');
            'e':WRITELN(' TARGET ANGLE IS PORT FWD.');
            'f':WRITELN(' TARGET ANGLE IS 000.');
            'g':WRITELN(' RELATIVE BRG IS STBD FWD.');
            'h':WRITELN(' RELATIVE BRG IS AFT.');
            'i':WRITELN(' RELATIVE BRG IS PORT FWD.');
            'j':WRITELN(' RELATIVE BRG IS 000.');
            'l':BEGIN
                WRITELN(' WHEN LIGHTING PATTERN IS RED OVER GREEN,');
                WRITELN(' CONTACT IS A SAILING VESSEL.')
            END;
            'm':BEGIN
                IF (TIME = 1) THEN
                    WRITELN(' WHEN DAYSHAPE IS TWO BLACK BALLS,')
                ELSE
                    WRITELN(' WHEN LIGHTING PATTERN IS RED OVER RED,');
                    WRITELN(' VESSEL IS NOT UNDER COMMAND.')
            END;
            'n':BEGIN
                IF (TIME = 1) THEN
                    WRITELN(' WHEN DAYSHAPE IS BALL DIAMOND BALL,')
                ELSE
                    WRITELN(' WHEN LIGHTING PATTERN IS RED OVER WHITE OVER RED,');
                    WRITELN(' VESSEL IS RESTRICTED IN ITS'' ABILITY TO MANEUVER.')
            END;
            'o':BEGIN
                WRITELN(' WHEN LIGHTING PATTERN IS RED OVER WHITE,');
                WRITELN(' VESSEL IS ENGAGED IN FISHING.')
            END;
            'p':BEGIN
                WRITELN(' WHEN LIGHTING IS GREEN OVER WHITE,');
                WRITELN(' VESSEL IS ENGAGED IN TRAWLING.')
            END;
        END;
    END;

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        END;
'q':BEGIN
    IF (TIME = 1) THEN
        WRITELN(' WHEN DAYSHAPE IS CYLINDER,')
    ELSE
        WRITELN(' WHEN LIGHTING PATTERN IS RED OVER RED OVER RED,')
        WRITELN(' VESSEL IS CONSTRAINED BY ITS'' DRAFT.')
    END;
'r':BEGIN
    WRITELN(' WHEN DAYSHAPE IS DOUBLE CONES,')
    WRITELN(' VESSEL IS ENGAGED IN FISHING OR TRAWLING.')
    END;
'u':WRITELN(' REDUCED VISIBILITY:RADAR CONTACT.')
'v':WRITELN(' OWN SHIP HAS SPECIAL STATUS.')
'z':WRITELN(' CONTACT HAS SPECIAL STATUS.')
'*':WRITELN(' REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.')
'A':WRITELN(' CONTACT IS A SAILING VESSEL UNDER SAIL.')
'B':WRITELN(' CONTACT IS CROSSING FROM PORT TO STBD.')
'C':WRITELN(' CONTACT IS CROSSING FROM STBD TO PORT.')
'D':WRITELN(' MEETING CONTACT HEAD TO HEAD.')
'E':WRITELN(' OVERTAKING THE CONTACT.')
'F':WRITELN(' BEING OVERTAKEN BY THE CONTACT.')
'G':BEGIN
    WRITELN(' YOU OBSERVE A STANDARD LIGHTING PATTERN OF:')
    WRITELN(' PORT AND STBD RUNNING,MASTHEAD,RANGE.')
    END;
'H':BEGIN
    WRITELN(' YOU OBSERVE A STANDARD LIGHTING PATTERN OF:')
    WRITELN(' PORT RUNNING,MASTHEAD,RANGE.')
    END;
'I':BEGIN
    WRITELN(' YOU OBSERVE A STANDARD LIGHTING PATTERN OF:')
    WRITELN(' STBD RUNNING,MASTHEAD,RANGE.')
    END;
'J':BEGIN
    WRITELN(' YOU OBSERVE A STANDARD LIGHTING PATTERN OF:')
    WRITELN(' STERN.')
    END;
'K':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN DAYSHAPE IS A BASKET, ')
        WRITELN(' THE VESSEL IS ENGAGED IN FISHING.')
    END;
'L':BEGIN
    IF (SETTING = 2) THEN BEGIN
        WRITELN(' WHEN DAYSHAPE IS TWO ORANGE & WHITE ')
        WRITELN(' VERTICALLY STRIPED BALLS. ')
    END;
    WRITELN(' THE VESSEL IS ENGAGED IN SERVICING NAVIGATION AIDS.')
    END;
'M':BEGIN
    IF (SETTING = 2) THEN BEGIN
        WRITELN(' WHEN DAYSHAPE IS A DIAMOND, TOP HALF BLACK & WHITE')
        WRITELN(' STRIPED, LOWER HALF SOLID RED, ')
    END;
    WRITELN(' THE VESSEL HAS A SUBMERGED TOW.')
    END;
'N':BEGIN
    IF (SETTING = 2) THEN BEGIN
        WRITELN(' WHEN DAYSHAPE IS A BLACK & WHITE STRIPED ')
        WRITELN(' BALL OVER A SOLID RED BALL, ')
    END;
    WRITELN(' THE VESSEL IS ENGAGED IN LAYING CABLE.')
    END;
'O':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN DAYSHAPE IS TWO BLACK BALLS, ')
        WRITELN(' THE VESSEL IS ENGAGED IN DREDGING.')
    END;

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'P':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN DAYSHAPE IS ONE BLACK BALL, ');
        WRITELN(' THE VESSEL IS ANCHORED.')
    END;
'Q':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN LIGHTING PATTERN IS RED OVER WHITE, ');
        WRITELN(' THE VESSEL IS ENGAGED IN FISHING.')
    END;
'R':BEGIN
    IF (SETTING = 2) THEN BEGIN
        WRITELN(' WHEN LIGHTING PATTERN IS WHITE OVER RED ');
        WRITELN(' OVER RED OVER WHITE, ')
    END;
    WRITELN(' THE VESSEL HAS A SUBMERGED TOW.')
    END;
'S':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN LIGHTING PATTERN IS WHITE OVER RED OVER RED, ');
        WRITELN(' THE VESSEL IS ENGAGED IN DREDGING.')
    END;
'T':BEGIN
    IF (SETTING = 2) THEN BEGIN
        WRITELN(' WHEN LIGHTING PATTERN IS WHITE OVER RED ');
        WRITELN(' OVER RED OVER RED OVER RED, ')
    END;
    WRITELN(' THE VESSEL IS ENGAGED IN DREDGING.')
    END;
'U':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN LIGHTING PATTERN IS RED OVER RED OVER RED, ');
        WRITELN(' THE VESSEL IS ENGAGED IN LAYING CABLE.')
    END;
'V':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN LIGHTING PATTERN IS ONE WHITE LIGHT FWD ');
        WRITELN(' AND ONE WHITE LIGHT AFT, ')
    END;
    WRITELN(' THE VESSEL IS ANCHORED.')
    END;
'W':BEGIN
    IF (SETTING = 2) THEN
        WRITELN(' WHEN LIGHTING PATTERN IS RED OVER RED, ');
        WRITELN(' THE VESSEL IS ENGAGED IN SERVICING NAVIGATION AIDS.')
    END;
END END;

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```
PROCEDURE CHECK2 (INPUT_ARRAY:SELECT_ARRAY;H:INTEGER;VAR OKAY:BOOLEAN);
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```

VAR
  D,E,P,Q:INTEGER;
  TIME_OK,DUPED,SAME_GROUP1,SAME_GROUP2,SAME_GROUP3,SAME_GROUP4:BOOLEAN;

BEGIN
  TIME_OK := FALSE;
  DUPED := FALSE;
  SAME_GROUP1 := FALSE;
  SAME_GROUP2 := FALSE;
  SAME_GROUP3 := FALSE;
  SAME_GROUP4 := FALSE;
  FOR D := 1 TO H-1 DO
    IF (INPUT_ARRAY[D] = 1) OR (INPUT_ARRAY[D] = 2) THEN
      TIME_OK := TRUE;
  IF NOT TIME_OK THEN BEGIN
    OKAY:= FALSE;
    WRITELN('NO TIME PERIOD WAS ENTERED. A TIME PERIOD MUST BE ENTERED');
    WRITELN('BEFORE A SITUATION CAN BE ANALYZED.');
    WRITELN('RE-ENTER SELECTION NUMBERS.');
  END;

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WRITELN('TO CONTINUE, PRESS ANY KEY.');
WHILE NOT KEYPRESSED DO
  DELAY(1);
WRITELN;WRITELN
END;
FOR D := 1 TO H-2 DO
  FOR E := D+1 TO H-1 DO
    IF (INPUT_ARRAY[D] = INPUT_ARRAY[E]) THEN BEGIN
      OKAY := FALSE;
      P := D;
      DUPED := TRUE
    END;
  IF DUPED THEN BEGIN
    WRITELN('SELECTION ',INPUT_ARRAY[P],', IS DUPLICATED.');
    WRITELN('RE-ENTER SELECTION NUMBERS.');
    WRITELN('TO CONTINUE, PRESS ANY KEY.');
    WHILE NOT KEYPRESSED DO
      DELAY(1);
    WRITELN;WRITELN
  END;
  FOR D := 1 TO H-2 DO
    FOR E := D+1 TO H-1 DO
      IF ((INPUT_ARRAY[D] IN [5,6,7,8,9]) AND (INPUT_ARRAY[E] IN
      [5,6,7,8,9])) THEN BEGIN
        OKAY := FALSE;
        P := D;
        Q := E;
        SAME_GROUP1 := TRUE
      END;
    IF SAME_GROUP1 THEN BEGIN
      WRITELN('SELECTIONS ',INPUT_ARRAY[P],', AND ',INPUT_ARRAY[Q],', CAN NOT');
      WRITELN('BE SELECTED TOGETHER BECAUSE ONLY ONE MEETING SITUATION CAN ');
      WRITELN('OCCUR BETWEEN TWO SHIPS AT ANY ONE TIME.');
      WRITELN('TO CONTINUE, PRESS ANY KEY.');
      WHILE NOT KEYPRESSED DO
        DELAY(1);
      WRITELN;WRITELN
    END;
    FOR D := 1 TO H-2 DO
      FOR E := D+1 TO H-1 DO
        IF ((INPUT_ARRAY[D] IN [10,11,12,13]) AND (INPUT_ARRAY[E] IN
        [10,11,12,13])) THEN BEGIN
          OKAY := FALSE;
          P := D;
          Q := E;
          SAME_GROUP2 := TRUE
        END;
      IF SAME_GROUP2 THEN BEGIN
        WRITELN('SELECTIONS ',INPUT_ARRAY[P],', AND ',INPUT_ARRAY[Q],', CAN NOT');
        WRITELN('BE SELECTED TOGETHER BECAUSE TWO DIFFERENT STANDARD LIGHTING');
        WRITELN('PATTERNS ARE NOT NORMALLY SEEN ON THE SAME SHIP.');
        WRITELN('RE-ENTER SELECTION NUMBERS.');
        WRITELN('TO CONTINUE, PRESS ANY KEY.');
        WHILE NOT KEYPRESSED DO
          DELAY(1);
        WRITELN;WRITELN
      END;
      FOR D := 1 TO H-2 DO
        FOR E := D+1 TO H-1 DO
          IF ((INPUT_ARRAY[D] IN [14,15,16,17,18,19]) AND (INPUT_ARRAY[E] IN
          [14,15,16,17,18,19])) THEN BEGIN
            OKAY := FALSE;
            P := D;
            Q := E;
            SAME_GROUP3 := TRUE
          END;
        IF SAME_GROUP3 THEN BEGIN
          WRITELN('SELECTIONS ',INPUT_ARRAY[P],', AND ',INPUT_ARRAY[Q],', CAN NOT');
          WRITELN('BE SELECTED TOGETHER BECAUSE TWO DIFFERENT DAYSHAPES ARE NOT')
        END;
      END;
    END;
  END;
END;

```

```

WRITELN('NORMALLY SEEN ON THE SAME SHIP. RE-ENTER SELECTION NUMBERS.');
WRITELN('TO CONTINUE, PRESS ANY KEY.');
WHILE NOT KEYPRESSED DO
  DELAY(1);
  WRITELN;WRITELN;
END;
FOR D := 1 TO H-2 DO
  FOR E := D+1 TO H-1 DO
    IF ((INPUT_ARRAY[D] IN [20,21,22,23,24,25,26]) AND (INPUT_ARRAY[E] IN
    [20,21,22,23,24,25,26])) THEN BEGIN
      OKAY := FALSE;
      P := D;
      Q := E;
      SAME_GROUP4 := TRUE
    END;
  IF SAME_GROUP2 THEN BEGIN
    WRITELN('SELECTIONS ',INPUT_ARRAY[P],' AND ',INPUT_ARRAY[Q],' CAN NOT');
    WRITELN('BE SELECTED TOGETHER BECAUSE TWO DIFFERENT SPECIAL LIGHTING');
    WRITELN('PATTERNS ARE NOT NORMALLY SEEN ON THE SAME SHIP.');
    WRITELN('RE-ENTER SELECTION NUMBERS.');
    WRITELN('TO CONTINUE, PRESS ANY KEY.');
    WHILE NOT KEYPRESSED DO
      DELAY(1);
      WRITELN;WRITELN;
    END END;
  
```

```

PROCEDURE INFER_ENG(XRULE:RULE_STR;SIZE,SETTING:INTEGER);

VAR
  FOUND:BOOLEAN;
  RULE_BASE_SIZE,H,I,J,B,COUNT:INTEGER;

BEGIN
  H := 1;
  FOUND := FALSE;
  IF (RULE_SET = 1) THEN
    RULE_BASE_SIZE := MAX_INL_RULE
  ELSE
    RULE_BASE_SIZE := MAX_INLD_RULE;
  WHILE NOT FOUND AND (H <= RULE_BASE_SIZE) DO BEGIN
    COUNT := 0;
    FOR I := 1 TO SIZE DO
      FOR J := 1 TO SIZE DO BEGIN
        IF (RULE_SET = 1) THEN BEGIN
          IF (XRULE[I] = INL_RULES[H].RULE FIG[J]) THEN
            COUNT := COUNT + 1;
          IF (COUNT=LENGTH(INL_RULES[H].RULE FIG))
            THEN
              BEGIN
                B := H;
                FOUND := TRUE;
              END;
        END;
        ELSE BEGIN
          IF (XRULE[I] = INLD_RULES[H].RULE FIG[J]) THEN
            COUNT := COUNT + 1;
          IF (COUNT=LENGTH(INLD_RULES[H].RULE FIG))
            THEN
              BEGIN
                B := H;
                FOUND := TRUE;
              END;
        END;
      END;
    END;
    H := H + 1;
  END;
  IF FOUND THEN BEGIN
    
```

```

CASE SETTING OF
1:BEGIN
    WRITELN;
    WRITELN('CONCLUSION IS:');
    IF (RULE_SET = 1) THEN
        MAP_CONL(INTL_RULES[B].CONL)
    ELSE
        MAP_CONL(INLD_RULES[B].CONL);
    WRITELN;
    WRITELN('WHEN THE FOLLOWING FACTS ARE TRUE:');
    IF (RULE_SET = 1) THEN
        DISPL_RULE(INTL_RULES[B].RULE FIG,SIZE,SETTING)
    ELSE
        DISPL_RULE(INLD_RULES[B].RULE FIG,SIZE,SETTING);
    WRITELN;
    WRITELN('TO CONTINUE, PRESS ANY KEY.');
    WHILE NOT KEYPRESSED DO
        DELAY(1);
    END;
2:BEGIN
    WRITELN;
    IF (RULE_SET = 1) THEN BEGIN
        DISPL_RULE(INTL_RULES[B].RULE FIG,SIZE,SETTING);
        MAP_CONL(INTL_RULES[B].CONL);
        END
    ELSE BEGIN
        DISPL_RULE(INLD_RULES[B].RULE FIG,SIZE,SETTING);
        MAP_CONL(INLD_RULES[B].CONL)
        END;
    WRITELN;
    END;
3:IF (RULE_SET = 1) THEN
    MAP_CONL(INTL_RULES[B].CONL)
    ELSE
        MAP_CONL(INLD_RULES[B].CONL);
    END;
END
ELSE BEGIN
    WRITELN;WRITELN('NO MATCH IN RULE BASE.');
    WRITELN('NO RISK OF COLLISION HAS BEEN DETECTED.');
    WRITELN;
    IF (SETTING = 2) OR (SETTING = 3) THEN
        WRITELN('RE-ENTER SELECTION NUMBERS.');
    CONTINUE := FALSE;
END END;

```

```

PROCEDURE DAY_ASPECT (VAR TA_DONE:BOOLEAN; BEARING:INTEGER; XCODE:SHORT_INT;
                      TA:SHRT_STR);

VAR
    OKAY:BOOLEAN;
    CODE,VIS_TA_INT:INTEGER;
    VIS_TA:SHRT_STR;
    VIS_QUAD,MOBD_QUAD:CHAR;

BEGIN
    REPEAT
        OKAY := TRUE;
        IF XCODE = 1 THEN BEGIN
            WRITELN;
            WRITELN('ENTER THE VISUAL TARGET ANGLE IN THREE DIGIT FORMAT.');
            END
        ELSE BEGIN
            WRITELN;
            WRITELN('ENTER MANEUVERING-BOARD-DETERMINED TARGET ANGLE IN');

```

```

WRITELN('THREE DIGIT FORMAT.');
END;
READLN(VIS_TA);
WRITELN;WRITELN(VIS_TA);
IF NOT(VIS_TA[1] IN ['0','1','2','3']) THEN BEGIN
  WRITELN('ILLEGAL ENTRY. RE-ENTER TARGET ANGLE.');?>
  OKAY := FALSE
END;
IF (VIS_TA[1] = '3') THEN
  IF NOT(VIS_TA[2] IN ['0','1','2','3','4','5']) THEN BEGIN
    WRITELN('ILLEGAL ENTRY. RE-ENTER TARGET ANGLE.');?>
    OKAY := FALSE;
  END
ELSE
  IF NOT(VIS_TA[2] IN ['0','1','2','3','4','5','6','7',
  '8','9']) THEN BEGIN
    WRITELN('ILLEGAL ENTRY. RE-ENTER TARGET ANGLE.');?>
    OKAY := FALSE
  END;
IF NOT(VIS_TA[3] IN ['0','1','2','3','4','5','6','7','8',
  '9']) THEN BEGIN
  WRITELN('ILLEGAL ENTRY. RE-ENTER TARGET ANGLE.');?>
  OKAY := FALSE
END;
UNTIL OKAY;
VAL(VIS_TA,VIS_TA_INT,CODE);
MAP_TA(VIS_QUAD,VIS_TA_INT);
MAP_TA(MOBD_QUAD,BEARING);
IF (VIS_QUAD = MOBD_QUAD) THEN BEGIN
  TA_DONE := TRUE;
  FACT FIG := FACT FIG + VIS_QUAD;
  MAX_FAX := MAX_FAX + 1;
END
ELSE BEGIN
  IF (XCODE = 1) THEN BEGIN
    WRITELN;
    WRITELN('PROGRAM-COMPUTED TARGET ANGLE DIFFERS FROM VISUAL TARGET');
    WRITELN('ANGLE AND WILL RESULT IN DIFFERENT MEETING SITUATIONS.');?>
    WRITELN('PROGRAM-COMPUTED TARGET ANGLE IS ',TA);
    WRITELN('RE-CHECK MANEUVERING BOARD SOLUTION AND VISUAL ASPECT.');?>
    WRITELN;
    END
  ELSE BEGIN
    WRITELN;
    WRITELN('PROGRAM-COMPUTED TARGET ANGLE DIFFERS FROM MANEUVERING BOARD');
    WRITELN('SOLUTION. PROGRAM-COMPUTED TARGET ANGLE IS ',TA);
    WRITELN('RE-CHECK SOLUTION.');?>
    WRITELN
  END;
END END;

```

```

PROCEDURE TGT_ANGLE;

VAR
  TARGET_ANGLE_INT,CODE:INTEGER;
  OKAY,TA_DONE:BOOLEAN;
  TARGET_ANGLE,CONTACT_HDG:SHRT_STR;
  XCODE:SHORT_INT;

BEGIN
  TA_DONE := FALSE;
  REPEAT
    REPEAT
      OKAY := TRUE;
      WRITELN;
      WRITELN('ENTER THE MANEUVER-BOARD-SOLUTION CONTACT HEADING IN');
      WRITELN('THREE DIGIT FORMAT.');?>

```

```

READLN(CONTACT_HDG);
WRITELN;WRITELN(CONTACT_HDG);WRITELN;
IF NOT(CONTACT_HDG[1] IN ['0','1','2','3']) THEN BEGIN
    WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
    OKAY := FALSE
END;
IF (CONTACT_HDG[1] = '3') THEN
    IF NOT(CONTACT_HDG[2] IN ['0','1','2','3','4','5']) THEN BEGIN
        WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
        OKAY := FALSE;
    END
ELSE
    IF NOT(CONTACT_HDG[2] IN ['0','1','2','3','4','5','6','7',
    '8','9']) THEN BEGIN
        WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
        OKAY := FALSE
    END;
IF NOT(CONTACT_HDG[3] IN ['0','1','2','3','4','5','6','7','8',
    '9']) THEN BEGIN
    WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
    OKAY := FALSE
END;
UNTIL OKAY;
CALC_TGT_ANG(TARGET_ANGLE,CONTACT_TRUE_BRG,CONTACT_HDG);
VAL(TARGET_ANGLE,TARGET_ANGLE_INT,CODE);
IF (TIME = 1) AND (LOW_VIS = 1) THEN BEGIN
    XCODE := 1;
    DAY_ASPECT(TA_DONE,TARGET_ANGLE_INT,XCODE,TARGET_ANGLE);
END
ELSE IF (TIME = 2) AND (LOW_VIS = 1) THEN
    NIGHT_ASPECT(TA_DONE,TARGET_ANGLE_INT,TARGET_ANGLE)
ELSE IF LOW_VIS = 2 THEN BEGIN
    XCODE := 2;
    DAY_ASPECT(TA_DONE,TARGET_ANGLE_INT,XCODE,TARGET_ANGLE)
END;
UNTIL TA_DONE END;

```

PROCEDURE RELATIVE_BRG;

```

VAR
OKAY:BOOLEAN;
REL_QUAD:CHAR;
YOUR_HDG,REL_BRG:SHRT_STR;
HTB_INT,YOUR_HDG_INT,REL_BRG_INT,CODE:INTEGER;

BEGIN
REPEAT
    OKAY := TRUE;
    WRITELN;
    WRITELN('ENTER THE CONTACT''S TRUE BEARING IN THREE DIGIT FORMAT.');
    READLN(CONTACT_TRUE_BRG);
    WRITELN;WRITELN(CONTACT_TRUE_BRG);
    IF NOT(CONTACT_TRUE_BRG[1] IN ['0','1','2','3']) THEN BEGIN
        WRITELN('ILLEGAL ENTRY. RE-ENTER BEARING.');
        OKAY := FALSE
    END;
    IF (CONTACT_TRUE_BRG[1] = '3') THEN
        IF NOT(CONTACT_TRUE_BRG[2] IN ['0','1','2','3','4','5']) THEN BEGIN
            WRITELN('ILLEGAL ENTRY. RE-ENTER BEARING.');
            OKAY := FALSE;
        END
    ELSE
        IF NOT(CONTACT_TRUE_BRG[2] IN ['0','1','2','3','4','5','6',
        '7','8','9']) THEN BEGIN
            WRITELN('ILLEGAL ENTRY. RE-ENTER BEARING.');
            OKAY := FALSE
        END;
    IF NOT(CONTACT_TRUE_BRG[3] IN ['0','1','2','3','4','5','6','7',
        '8','9']) THEN BEGIN

```

```

'8','9']) THEN BEGIN
  WRITELN('ILLEGAL ENTRY. RE-ENTER BEARING.');
  OKAY := FALSE
END;
UNTIL OKAY;
REPEAT
  OKAY := TRUE;
  WRITELN;
  WRITELN('ENTER YOUR SHIP''S HEADING IN THREE DIGIT FORMAT.');
  READLN(YOUR_HDG);
  WRITELN;WRITELN(YOUR_HDG);
  IF NOT(YOUR_HDG[1] IN ['0','1','2','3']) THEN BEGIN
    WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
    OKAY := FALSE
  END;
  IF (YOUR_HDG[1] = '3') THEN
    IF NOT(YOUR_HDG[2] IN ['0','1','2','3','4','5']) THEN BEGIN
      WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
      OKAY := FALSE;
    END
  ELSE
    IF NOT(YOUR_HDG[2] IN ['0','1','2','3','4','5','6','7','8',
      '9']) THEN BEGIN
      WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
      OKAY := FALSE;
    END;
    IF NOT(YOUR_HDG[3] IN ['0','1','2','3','4','5','6','7',
      '8','9']) THEN BEGIN
      WRITELN('ILLEGAL ENTRY. RE-ENTER HEADING.');
      OKAY := FALSE
    END;
  UNTIL OKAY;
VAL(CONTACT_TRUE_BRG,HTB_INT,CODE);
VAL(YOUR_HDG,YOUR_HDG_INT,CODE);
REL_BRG_INT := HTB_INT - YOUR_HDG_INT;
IF (REL_BRG_INT < 0) THEN
  REL_BRG_INT := REL_BRG_INT + 360;
MAP_RB(REL_QUAD,REL_BRG_INT);
FACT FIG := FACT FIG + REL_QUAD;
MAX_FAX := MAX_FAX + 1 END;

```

```

PROCEDURE MAP_SPEC_STAT(VAR RULE:RULE_STR;CODE:INTEGER);

BEGIN
  CASE CODE OF
    6:RULE := 'l';
    12,7:RULE := 'm';
    8,13:RULE := 'n';
    9:RULE := 'o';
    10:RULE := 'p'; 11,15:RULE := 'q';
    14:RULE := 'r';
  END; END;

```

```

PROCEDURE MAP_INTNL (CODE:INTEGER);

CONST
  LEN = 1;

VAR
  SHORT_RULE:RULE_STR;

BEGIN
  CASE CODE OF
    1:BEGIN
      MID_RULE := MID_RULE + 'a';
    END;
  END;

```

```

MID_SIZE := MID_SIZE + 1;
TIME := 1;
TIME1 := 1;
FACT FIG := FACT FIG + 'a';
MAX_FAX := MAX_FAX + 1
END;
2:BEGIN
  MID_RULE := MID_RULE + 'b';
  MID_SIZE := MID_SIZE + 1;
  TIME := 2;
  TIME2 := 2;
  FACT FIG := FACT FIG + 'b';
  MAX_FAX := MAX_FAX + 1
END;
3:BEGIN
  FOG := 3;
  MID_RULE := MID_RULE + 'u';
  MID_SIZE := MID_SIZE + 1;
  FACT FIG := FACT FIG + 'u';
  MAX_FAX := MAX_FAX + 1;
  LOW_VIS := 2
END;
4:BEGIN
  FOG2 := 4;
  FOG_SIG_CONTACT := TRUE;
  FACT FIG := FACT FIG + '*';
  MAX_FAX := MAX_FAX + 1;
  MID_RULE := MID_RULE + 's';
  MID_SIZE := MID_SIZE + 1
END;
5:BEGIN
  MID_RULE := MID_RULE + 'v';
  MID_SIZE := MID_SIZE + 1;
  FACT FIG := FACT FIG + 'v';
  MAX_FAX := MAX_FAX + 1
END;
6,7,8,9,10,11,12,
13,14,15:BEGIN
  MAP_SPEC_STAT(SHORT_RULE, CODE);
  IF CODE IN [12,13,14,15] THEN BEGIN
    DSHAPE := CODE;
    MID_RULE := MID_RULE + 'w';
    MID_SIZE := MID_SIZE + 1;
    WRITELN('INTERPRETATION OF DAYSHAPE IS:');
    END
  ELSE BEGIN
    SPEC_LTS := CODE;
    MID_RULE := MID_RULE + 'x';
    MID_SIZE := MID_SIZE + 1;
    WRITELN('INTERPRETATION OF SPECIAL LIGHTS IS:');
    END;
    SETTING := 2;
    INFER_ENG(SHORT_RULE, LEN, SETTING)
  END;
16,17,18,19:BEGIN
  RUN_LTS := CODE;
  MID_RULE := MID_RULE + 't';
  MID_SIZE := MID_SIZE + 1;
  LTGCODE := CODE
END;
END END;

```

PROCEDURE MENU;

TYPE

NUM_TYPE = SET OF 1..26;

```

VAR
  INPUT_ARRAY:SELECT_ARRAY;
  OKAY:BOOLEAN;
  DELIM:CHAR;
  LEN,CODE,NUM,R,G,H,I,DELIMPOS:INTEGER;
  LONGCODE:INPUT_STR;
  SHORT_RULE:RULE_STR;
  TEMP:STRING[3];
  SELECT_SET,SPEC_SET:NUM_TYPE;

BEGIN
  SELECT_SET := [1..26];
  DELIM := ',';
  REPEAT
    CLRSCR;
    I := 0;
    H := 1;
    OKAY := TRUE;
    IF (RULE_SET = 1) THEN BEGIN
      PRINT_MENU;
      READLN(LONGCODE);
      WRITELN(LONGCODE);WRITELN;
      END
    ELSE
      PRINT_MENU2(LONGCODE);
    LEN := LENGTH(LONGCODE);
    FOR R := 1 TO LEN DO
      WHILE (LONGCODE[R] = ' ') AND (LENGTH(LONGCODE) >= 1) DO
        DELETE(LONGCODE,R,1);
    IF (LENGTH(LONGCODE) = 0) THEN BEGIN
      OKAY := FALSE;
      WRITELN;WRITELN('NO SELECTION WAS MADE.');
      END
    ELSE BEGIN
      REPEAT
        IF (LENGTH(LONGCODE) > 2) THEN BEGIN
          DELIMPOS := POS(DELIM,LONGCODE);
          IF (DELIMPOS = 0) AND (I > 0) THEN BEGIN
            DELETE(LONGCODE,1,23);
            OKAY := FALSE
          END;
          TEMP := COPY(LONGCODE,1,DELIMPOS-1);
          DELETE(LONGCODE,1,DELIMPOS);
          END
        ELSE BEGIN
          TEMP := LONGCODE;
          DELETE(LONGCODE,1,2)
        END;
        END;
        VAL(TEMP,NUM,CODE);
        IF (NUM IN SELECT_SET) AND (CODE=0) THEN BEGIN
          INPUT_ARRAY[H] := NUM;
          H := H+1;
          END
        ELSE
          OKAY := FALSE;
        I := I + 1;
      UNTIL (LENGTH(LONGCODE) = 0)
    END;
    IF NOT OKAY THEN BEGIN
      WRITELN('ILLEGAL ENTRY. RE-ENTER SELECTION NUMBERS.');?>
      WRITELN('TO CONTINUE, PRESS ANY KEY.');
      WHILE NOT KEYPRESSED DO
        DELAY(1);
      WRITELN;WRITELN
    END;
    IF OKAY THEN
      IF (RULE_SET = 1) THEN
        CHECK(INPUT_ARRAY,H,OKAY)
      ELSE

```

```

        CHECK2(INPUT_ARRAY,H,OKAY);
UNTIL OKAY;
FOR G := 1 TO H-1 DO
  IF (RULE_SET = 1) THEN
    MAP_INTNL(INPUT_ARRAY[G])
  ELSE BEGIN
    MAP_INLAND(INPUT_ARRAY[G],SHORT_RULE);
    SPEC_SET := [14..26];
    IF INPUT_ARRAY[G] IN SPEC_SET THEN BEGIN
      LEN := 1;
      SETTING := 2;
      DISPL_RULE(SHORT_RULE,LEN,SETTING)
    END;
  END END;

BEGIN MAIN
  GOOD := FALSE;
  QUIT := FALSE;
REPEAT
  CLRSCR;
  WRITELN('WHICH SET OF NAVIGATION RULES ARE CURRENTLY IN EFFECT?');
  WRITELN('MAKE A NUMBER SELECTION THEN PRESS THE ENTER KEY.');
  WRITELN(' 1. INTERNATIONAL');
  WRITELN(' 2. INLAND');
  READLN(RULE_SET);
  WRITELN(RULE_SET);
  IF (RULE_SET <> 1) AND (RULE_SET <> 2) THEN BEGIN
    WRITELN;
    WRITELN('ILLEGAL ENTRY. RE-ENTER SELECTION.');
    WRITELN('TO CONTINUE, PRESS ANY KEY.');?>
    WHILE NOT KEYPRESSED DO
      DELAY(1);
    END
  ELSE
    GOOD := TRUE;
UNTIL GOOD;
IF (RULE_SET = 1) THEN
  BUILD_RULES
ELSE
  BUILD_RULES2;
REPEAT
  LOW_VIS := 1;
  FOG_SIG_CONTACT := FALSE;
  CONTINUE := TRUE;
  MID_RULE := ' ';
  MID_SIZE := 0;
  FACT FIG := ' ';
  MAX_FAX := 0;
  MENU;
  SETTING := 3;
  DELETE(MID_RULE,1,1);
  INFER_ENG(MID_RULE,MID_SIZE,SETTING);
  IF CONTINUE THEN BEGIN
    IF NOT FOG_SIG_CONTACT AND (RULE_SET = 1) THEN BEGIN
      RELATIVE_BRG;
      TGT_ANGLE
    END;
    DELETE(FACT FIG,1,1);
    SETTING := 1;
    INFER_ENG(FACT FIG,MAX_FAX,SETTING);
    WRITELN('DO YOU WISH TO ANALYZE ANOTHER CONTACT?');
    WRITELN('IF SO, ENTER A CAPITAL Y, THEN PRESS THE ENTER KEY.');
    WRITELN('OTHERWISE, ENTER ANY OTHER LETTER, THEN PRESS THE ENTER KEY.');
    READLN(ANS);
    WRITELN(ANS);
    IF (ANS <> 'Y') AND (ANS <> 'y') THEN
      QUIT := TRUE;
  END;

```

```
END
ELSE BEGIN
  WRITELN('TO CONTINUE, PRESS ANY KEY.');
  WHILE NOT KEYPRESSED DO
    DELAY(1);
END;
UNTIL QUIT END.
```

APPENDIX B

SAMPLE USER SESSIONS

WHICH SET OF NAVIGATION RULES ARE CURRENTLY IN EFFECT?
MAKE A NUMBER SELECTION THEN PRESS THE ENTER KEY.

1. INTERNATIONAL
2. INLAND

1
ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA.

EXAMPLE: 2,6,16

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:RADAR CONTACT.
4. REDUCED VISIBILITY:SOUND SIGNAL HEARD FWD OF BEAM.
5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.

6. RED OVER GREEN. 9. RED OVER WHITE.
7. RED OVER RED. 10. GREEN OVER WHITE.
8. RED OVER WHITE OVER RED. 11. RED OVER RED OVER RED.

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.

12. TWO BLACK BALLS. 14. DOUBLE CONES.
13. BALL DIAMOND BALL. 15. CYLINDER.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.
17. PORT RUNNING, MASTHEAD, RANGE.
18. STBD RUNNING, MASTHEAD, RANGE.
19. STERN.

1,13,18

INTERPRETATION OF DAYSHAPE IS:

WHEN DAYSHAPE IS BALL DIAMOND BALL,
VESSEL IS RESTRICTED IN ITS' ABILITY TO MANEUVER.

SEMANTIC ERROR.

SELECTIONS 1 AND 18 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.

RE-ENTER SELECTION NUMBERS.

TO CONTINUE, PRESS ANY KEY.

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA.

EXAMPLE: 2,6,16

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:RADAR CONTACT.
4. REDUCED VISIBILITY:SOUND SIGNAL HEARD FWD OF BEAM.
5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.

6. RED OVER GREEN. 9. RED OVER WHITE.
7. RED OVER RED. 10. GREEN OVER WHITE.
8. RED OVER WHITE OVER RED. 11. RED OVER RED OVER RED.

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.

12. TWO BLACK BALLS. 14. DOUBLE CONES.
13. BALL DIAMOND BALL. 15. CYLINDER.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.
17. PORT RUNNING, MASTHEAD, RANGE.
18. STBD RUNNING, MASTHEAD, RANGE.
19. STERN.

1

ENTER THE CONTACT'S TRUE BEARING IN THREE DIGIT FORMAT.

182

ENTER YOUR SHIP'S HEADING IN THREE DIGIT FORMAT.

161

ENTER THE MANEUVER-BOARD-SOLUTION CONTACT HEADING IN THREE DIGIT FORMAT.

070

ENTER THE VISUAL TARGET ANGLE IN THREE DIGIT FORMAT.

160

PROGRAM-COMPUTED TARGET ANGLE DIFFERS FROM VISUAL TARGET ANGLE AND WILL RESULT IN DIFFERENT MEETING SITUATIONS.

PROGRAM-COMPUTED TARGET ANGLE IS 292

RE-CHECK MANEUVERING BOARD SOLUTION AND VISUAL ASPECT.

ENTER THE MANEUVER-BOARD-SOLUTION CONTACT HEADING IN THREE DIGIT FORMAT.

070

ENTER THE VISUAL TARGET ANGLE IN THREE DIGIT FORMAT.

345

CONCLUSION IS:

YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.

TURN STBD IF POSSIBLE.

SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.

WHEN THE FOLLOWING FACTS ARE TRUE:

TARGET ANGLE IS PORT FWD.

TO CONTINUE, PRESS ANY KEY.

DO YOU WISH TO ANALYZE ANOTHER CONTACT?

IF SO, ENTER A CAPITAL Y, THEN PRESS THE ENTER KEY.

OTHERWISE, ENTER ANY OTHER LETTER, THEN PRESS THE ENTER KEY.

Y

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA.

EXAMPLE: 2,6,16

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY: RADAR CONTACT.
4. REDUCED VISIBILITY: SOUND SIGNAL HEARD FWD OF BEAM.
5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.

6. RED OVER GREEN.	9. RED OVER WHITE.
7. RED OVER RED.	10. GREEN OVER WHITE.
8. RED OVER WHITE OVER RED.	11. RED OVER RED OVER RED.

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.

12. TWO BLACK BALLS.	14. DOUBLE CONES.
13. BALL DIAMOND BALL.	15. CYLINDER.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.
17. PORT RUNNING, MASTHEAD, RANGE.
18. STBD RUNNING, MASTHEAD, RANGE.
19. STERN.

5,2,154

ILLEGAL ENTRY. RE-ENTER SELECTION NUMBERS.
TO CONTINUE, PRESS ANY KEY.

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING
CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED
BY A COMMA.

EXAMPLE: 2,6,16

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:RADAR CONTACT.
4. REDUCED VISIBILITY:SOUND SIGNAL HEARD FWD OF BEAM.
5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.

6. RED OVER GREEN. 9. RED OVER WHITE.
7. RED OVER RED. 10. GREEN OVER WHITE.
8. RED OVER WHITE OVER RED. 11. RED OVER RED OVER RED.

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.

12. TWO BLACK BALLS. 14. DOUBLE CONES.
13. BALL DIAMOND BALL. 15. CYLINDER.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.
17. PORT RUNNING, MASTHEAD, RANGE.
18. STBD RUNNING, MASTHEAD, RANGE.
19. STERN.

1,14,1

SELECTION 1 IS DUPLICATED.
RE-ENTER SELECTION NUMBERS.
TO CONTINUE, PRESS ANY KEY.

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING
CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED
BY A COMMA.

EXAMPLE: 2,6,16

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:RADAR CONTACT.
4. REDUCED VISIBILITY:SOUND SIGNAL HEARD FWD OF BEAM.
5. OWN SHIP CURRENTLY HAS SPECIAL STATUS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS IS OBSERVED.

6. RED OVER GREEN. 9. RED OVER WHITE.
7. RED OVER RED. 10. GREEN OVER WHITE.
8. RED OVER WHITE OVER RED. 11. RED OVER RED OVER RED.

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED.

12. TWO BLACK BALLS. 14. DOUBLE CONES.
13. BALL DIAMOND BALL. 15. CYLINDER.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED.

16. PORT AND STBD RUNNING, MASTHEAD, RANGE.
17. PORT RUNNING, MASTHEAD, RANGE.
18. STBD RUNNING, MASTHEAD, RANGE.
19. STERN.

18,2,11

INTERPRETATION OF SPECIAL LIGHTS IS:

WHEN LIGHTING PATTERN IS RED OVER RED OVER RED,
VESSEL IS CONSTRAINED BY ITS' DRAFT.

ENTER THE CONTACT'S TRUE BEARING IN THREE DIGIT FORMAT.

013

ENTER YOUR SHIP'S HEADING IN THREE DIGIT FORMAT.

101

ENTER THE MANEUVER-BOARD-SOLUTION CONTACT HEADING IN THREE DIGIT FORMAT.

177

CONCLUSION IS:

CONTACT HAS SPECIAL STATUS. YOU ARE GIVE-WAY VESSEL.
MANEUVER TO AVOID CONTACT. TURN STBD IF POSSIBLE.
SHOW ONE LIGHT FLASH TO SIGNAL A STBD TURN.

WHEN THE FOLLOWING FACTS ARE TRUE:

TARGET ANGLE IS STBD FWD.
CONTACT HAS SPECIAL STATUS.

TO CONTINUE, PRESS ANY KEY.

DO YOU WISH TO ANALYZE ANOTHER CONTACT?

IF SO, ENTER A CAPITAL Y, THEN PRESS THE ENTER KEY.

OTHERWISE, ENTER ANY OTHER LETTER, THEN PRESS THE ENTER KEY.

N

WHICH SET OF NAVIGATION RULES ARE CURRENTLY IN EFFECT?
MAKE A NUMBER SELECTION THEN PRESS THE ENTER KEY.

1. INTERNATIONAL
2. INLAND

2

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA. EXAMPLE: 2,6 . A SECOND MENU WILL DISPLAY ADDITIONAL CONDITIONS WHEN THE ENTER KEY IS PRESSED.

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:FOG SIGNAL HEARD FWD OF BEAM.
4. CONTACT IS A SAILING VESSEL UNDER SAIL.

ONE OF THE FOLLOWING MEETING SITUATIONS EXISTS:

5. CONTACT CROSSING FROM PORT TO STBD.
6. CONTACT CROSSING FROM STBD TO PORT.
7. MEETING CONTACT HEAD TO HEAD.
8. OVERTAKING CONTACT.
9. BEING OVERTAKEN BY CONTACT.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED:

10. PORT AND STBD RUNNING, MASTHEAD, RANGE.
11. PORT RUNNING, MASTHEAD, RANGE.
12. STBD RUNNING, MASTHEAD, RANGE.
13. STERN.

1,5

CONTINUE NUMBER SELECTION WITH THE CONDITIONS BELOW. ONLY ONE SELECTION WILL NORMALLY BE MADE FROM THIS MENU, SO NO COMMAS SHOULD BE NEEDED. EXAMPLE: 17

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED:

14. BASKET.
19. ONE BLACK BALL.
15. TWO ORANGE & WHITE VERTICALLY STRIPED BALLS.
16. DIAMOND, TOP HALF BLACK & WHITE STRIPED, LOWER HALF SOLID RED.
17. BLACK & WHITE STRIPED BALL OVER SOLID RED BALL.
18. TWO BLACK BALLS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS:

20. RED OVER WHITE.
26. RED OVER RED.
21. WHITE OVER RED OVER RED OVER WHITE.
22. WHITE OVER RED OVER RED.

23. WHITE OVER RED OVER RED OVER RED OVER RED.
24. RED OVER RED OVER RED.
25. ONE WHITE FWD AND ONE WHITE AFT.

14

THE COMPLETE SELECTION FOR THIS INLAND SITUATION IS 1,5,14
INTERPRETATION OF DAYSHAPE IS:

WHEN DAYSHAPE IS A BASKET,
THE VESSEL IS ENGAGED IN FISHING.

CONCLUSION IS:

YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.

WHEN THE FOLLOWING FACTS ARE TRUE:

CONTACT IS CROSSING FROM PORT TO STBD.

TO CONTINUE, PRESS ANY KEY.

DO YOU WISH TO ANALYZE ANOTHER CONTACT?

IF SO, ENTER A CAPITAL Y, THEN PRESS THE ENTER KEY.
OTHERWISE, ENTER ANY OTHER LETTER, THEN PRESS THE ENTER KEY.

Y

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING
CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED
BY A COMMA. EXAMPLE: 2,6. A SECOND MENU WILL DISPLAY ADDITIONAL
CONDITIONS WHEN THE ENTER KEY IS PRESSED.

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY: FOG SIGNAL HEARD FWD OF BEAM.
4. CONTACT IS A SAILING VESSEL UNDER SAIL.

ONE OF THE FOLLOWING MEETING SITUATIONS EXISTS:

5. CONTACT CROSSING FROM PORT TO STBD.
6. CONTACT CROSSING FROM STBD TO PORT.
7. MEETING CONTACT HEAD TO HEAD.
8. OVERTAKING CONTACT.
9. BEING OVERTAKEN BY CONTACT.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED:

10. PORT AND STBD RUNNING, MASTHEAD, RANGE.
11. PORT RUNNING, MASTHEAD, RANGE.
12. STBD RUNNING, MASTHEAD, RANGE.
13. STERN.

3,2,5,12

CONTINUE NUMBER SELECTION WITH THE CONDITIONS BELOW. ONLY ONE
SELECTION WILL NORMALLY BE MADE FROM THIS MENU, SO NO COMMAS
SHOULD BE NEEDED. EXAMPLE: 17

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED:

14. BASKET.
15. TWO ORANGE & WHITE VERTICALLY STRIPED BALLS.
16. DIAMOND, TOP HALF BLACK & WHITE STRIPED, LOWER HALF SOLID RED.
17. BLACK & WHITE STRIPED BALL OVER SOLID RED BALL.
18. TWO BLACK BALLS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS:

20. RED OVER WHITE.
21. WHITE OVER RED OVER RED OVER WHITE.
22. WHITE OVER RED OVER RED.
23. WHITE OVER RED OVER RED OVER RED OVER RED.
24. RED OVER RED OVER RED.
25. ONE WHITE FWD AND ONE WHITE AFT.

THE COMPLETE SELECTION FOR THIS INLAND SITUATION IS 3,2,5,12
SEMANTIC ERROR.

SELECTIONS 12 AND 3 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED
VISIBILITY CONDITIONS.

RE-ENTER SELECTION NUMBERS.

TO CONTINUE, PRESS ANY KEY.

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING

CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA. EXAMPLE: 2,6 . A SECOND MENU WILL DISPLAY ADDITIONAL CONDITIONS WHEN THE ENTER KEY IS PRESSED.

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:FOG SIGNAL HEARD FWD OF BEAM.
4. CONTACT IS A SAILING VESSEL UNDER SAIL.

ONE OF THE FOLLOWING MEETING SITUATIONS EXISTS:

5. CONTACT CROSSING FROM PORT TO STBD.
6. CONTACT CROSSING FROM STBD TO PORT.
7. MEETING CONTACT HEAD TO HEAD.
8. OVERTAKING CONTACT.
9. BEING OVERTAKEN BY CONTACT.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED:

10. PORT AND STBD RUNNING, MASTHEAD, RANGE.
11. PORT RUNNING, MASTHEAD, RANGE.
12. STBD RUNNING, MASTHEAD, RANGE.
13. STERN.

2,3

CONTINUE NUMBER SELECTION WITH THE CONDITIONS BELOW. ONLY ONE SELECTION WILL NORMALLY BE MADE FROM THIS MENU, SO NO COMMAS SHOULD BE NEEDED. EXAMPLE: 17

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED:

14. BASKET.
15. TWO ORANGE & WHITE VERTICALLY STRIPED BALLS.
16. DIAMOND, TOP HALF BLACK & WHITE STRIPED, LOWER HALF SOLID RED.
17. BLACK & WHITE STRIPED BALL OVER SOLID RED BALL.
18. TWO BLACK BALLS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS:

20. RED OVER WHITE.
21. WHITE OVER RED OVER RED OVER WHITE.
22. WHITE OVER RED OVER RED.
23. WHITE OVER RED OVER RED OVER RED OVER RED.
24. RED OVER RED OVER RED.
25. ONE WHITE FWD AND ONE WHITE AFT.

THE COMPLETE SELECTION FOR THIS INLAND SITUATION IS 2,3

CONCLUSION IS:

REDUCE SPEED TO BARE STEERAGE-WAY. PROCEED WITH EXTREME CAUTION UNTIL THE DANGER OF COLLISION IS OVER.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

TO CONTINUE, PRESS ANY KEY.

DO YOU WISH TO ANALYZE ANOTHER CONTACT?

IF SO, ENTER A CAPITAL Y, THEN PRESS THE ENTER KEY.

OTHERWISE, ENTER ANY OTHER LETTER, THEN PRESS THE ENTER KEY.

Y

ENTER THE CORRESPONDING NUMBER FOR ANY OF THE FOLLOWING CONDITIONS THAT CURRENTLY EXIST. NUMBERS SHOULD BE SEPARATED BY A COMMA. EXAMPLE: 2,6 . A SECOND MENU WILL DISPLAY ADDITIONAL CONDITIONS WHEN THE ENTER KEY IS PRESSED.

1. TIME PERIOD IS AFTER SUNRISE AND BEFORE SUNSET.
2. TIME PERIOD IS AFTER SUNSET AND BEFORE SUNRISE.
3. REDUCED VISIBILITY:FOG SIGNAL HEARD FWD OF BEAM.
4. CONTACT IS A SAILING VESSEL UNDER SAIL.

ONE OF THE FOLLOWING MEETING SITUATIONS EXISTS:

5. CONTACT CROSSING FROM PORT TO STBD.
6. CONTACT CROSSING FROM STBD TO PORT.
7. MEETING CONTACT HEAD TO HEAD.
8. OVERTAKING CONTACT.
9. BEING OVERTAKEN BY CONTACT.

ONE OF THE FOLLOWING STANDARD LIGHTING PATTERNS IS OBSERVED:

10. PORT AND STBD RUNNING, MASTHEAD, RANGE.
11. PORT RUNNING, MASTHEAD, RANGE.
12. STBD RUNNING, MASTHEAD, RANGE.

13. STERN.
6,2,11

CONTINUE NUMBER SELECTION WITH THE CONDITIONS BELOW. ONLY ONE SELECTION WILL NORMALLY BE MADE FROM THIS MENU, SO NO COMMAS SHOULD BE NEEDED. EXAMPLE: 17

ONE OF THE FOLLOWING DAYSHAPES IS OBSERVED:

- 14. BASKET.
- 19. ONE BLACK BALL.
- 15. TWO ORANGE & WHITE VERTICALLY STRIPED BALLS.
- 16. DIAMOND, TOP HALF BLACK & WHITE STRIPED, LOWER HALF SOLID RED.
- 17. BLACK & WHITE STRIPED BALL OVER SOLID RED BALL.
- 18. TWO BLACK BALLS.

ONE OF THE FOLLOWING SPECIAL LIGHTING PATTERNS:

- 20. RED OVER WHITE.
- 26. RED OVER RED.
- 21. WHITE OVER RED OVER RED OVER WHITE.
- 22. WHITE OVER RED OVER RED.
- 23. WHITE OVER RED OVER RED OVER RED OVER RED.
- 24. RED OVER RED OVER RED.
- 25. ONE WHITE FWD AND ONE WHITE AFT.

22

THE COMPLETE SELECTION FOR THIS INLAND SITUATION IS 6,2,11,22
INTERPRETATION OF SPECIAL LIGHTS IS:

WHEN LIGHTING PATTERN IS WHITE OVER RED OVER RED,
THE VESSEL IS ENGAGED IN DREDGING.

CONCLUSION IS:

WHEN WITHIN ONE MILE OF CONTACT, INDICATE INTENTION TO PASS
WITH ONE LONG BLAST. CONTACT WILL DIRECT YOU TO PROPER SIDE
FOR PASSAGE WITH ONE SHORT BLAST FOR A STBD PASSAGE OR TWO
SHORT BLASTS FOR A PORT PASSAGE. ANSWER WITH SAME SIGNAL TO
ACKNOWLEDGE. IF CONTACT SOUNDS DANGER SIGNAL, FOUR OR MORE
SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO PASS.
SLOW DOWN OR STOP AND AWAIT FURTHER SIGNAL.

WHEN THE FOLLOWING FACTS ARE TRUE:
THE VESSEL IS ENGAGED IN DREDGING.

TO CONTINUE, PRESS ANY KEY.

DO YOU WISH TO ANALYZE ANOTHER CONTACT?

IF SO, ENTER A CAPITAL Y, THEN PRESS THE ENTER KEY.

OTHERWISE, ENTER ANY OTHER LETTER, THEN PRESS THE ENTER KEY.

N

APPENDIX C

INTERNATIONAL RULES: CODED AND DECODED

RULE IS:wstx 21

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 12 AND 4 AND 6 AND

RUN LTS ARE NOT COMPATIBLE. LIGHTS OR DAYSHAPES CAN NOT
NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

DAYSHAPE IS BASKET.

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

RULE IS:axt 10

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 6 AND 18

ARE NOT COMPATIBLE. LIGHTS OF ANY TYPE ARE NOT NORMALLY
DISPLAYED AFTER SUNRISE.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:wst 20

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 12 AND 18 AND 4

ARE NOT COMPATIBLE. LIGHTS OR DAYSHAPES CAN NOT
NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

DAYSHAPE IS BASKET.

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:xst 15

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 18 AND 6 AND 3 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED
VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:at 9

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 18 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:ax 8
CONCLUSION IS:
SEMANTIC ERROR.

SELECTIONS 1 AND 6 ARE NOT COMPATIBLE.
LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.
WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

WHEN SPECIAL LIGHTING CONFIGURATION IS:
RED OVER WHITE

RULE IS:sw 12

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 12 AND 3 ARE NOT COMPATIBLE.
DAYSHAPES CAN NOT NORMALLY BE SEEN DURING REDUCED
VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.
DAYSHAPE IS BASKET.

RULE IS:ab 19

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 2 ARE NOT COMPATIBLE.
THE TWO POSSIBLE TIME-PERIODS CAN NOT OCCUR TOGETHER.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

TIME = NIGHT.

RULE IS:st 14

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 18 AND 3 ARE NOT COMPATIBLE.
LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED
VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.
WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:ux 13

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 6 AND 3 ARE NOT COMPATIBLE.
LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED
VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:RADAR CONTACT.

WHEN SPECIAL LIGHTING CONFIGURATION IS:
RED OVER WHITE

RULE IS:bw 11

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 12 ARE NOT COMPATIBLE.
DAYSHAPES ARE NOT NORMALLY DISPLAYED AFTER SUNSET.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = NIGHT.

DAYSHAPE IS BASKET.

RULE IS:cz 2

CONCLUSION IS:

CONTACT HAS SPECIAL STATUS. YOU ARE GIVE-WAY VESSEL.
MANEUVER TO AVOID CONTACT. TURN STBD IF POSSIBLE.
SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.

WHEN THE FOLLOWING FACTS ARE TRUE:

TARGET ANGLE IS STBD FWD.

CONTACT HAS SPECIAL STATUS.

RULE IS:c 1

CONCLUSION IS:

YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS STBD FWD.

RULE IS:ev 4

CONCLUSION IS:

OWN SHIP HAS SPECIAL STATUS. YOU ARE STAND-ON VESSEL.
MAINTAIN COURSE AND SPEED.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS PORT FWD.
OWN SHIP HAS SPECIAL STATUS.

RULE IS:e 3

CONCLUSION IS:

YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.
TURN STBD IF POSSIBLE.
SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS PORT FWD.

RULE IS:h 1

CONCLUSION IS:

YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.
WHEN THE FOLLOWING FACTS ARE TRUE:
RELATIVE BRG IS AFT.

RULE IS:d 3

CONCLUSION IS:

YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.
TURN STBD IF POSSIBLE.
SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS AFT.

RULE IS:fv 4

CONCLUSION IS:

OWN SHIP HAS SPECIAL STATUS. YOU ARE STAND-ON VESSEL.
MAINTAIN COURSE AND SPEED.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS 000.
OWN SHIP HAS SPECIAL STATUS.

RULE IS:fz 3

CONCLUSION IS:

YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.
TURN STBD IF POSSIBLE.
SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS 000.
CONTACT HAS SPECIAL STATUS.

RULE IS:f 5

CONCLUSION IS:

BOTH SHIPS MUST GIVE WAY. ALTER COURSE TO STBD TO
AVOID CONTACT.
SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.
WHEN THE FOLLOWING FACTS ARE TRUE:
TARGET ANGLE IS 000.

RULE IS:l 6

CONCLUSION IS:

CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN LIGHTING PATTERN IS RED OVER GREEN,
CONTACT IS A SAILING VESSEL.

RULE IS:m 6
CONCLUSION IS:
CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN DAYSHAPE IS TWO BLACK BALLS,
VESSEL IS NOT UNDER COMMAND.

RULE IS:n 6
CONCLUSION IS:
CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN DAYSHAPE IS BALL DIAMOND BALL,
VESSEL IS RESTRICTED IN ITS' ABILITY TO MANEUVER.

RULE IS:o 6
CONCLUSION IS:
CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN LIGHTING PATTERN IS RED OVER WHITE,
VESSEL IS ENGAGED IN FISHING.

RULE IS:p 6
CONCLUSION IS:
CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN LIGHTING IS GREEN OVER WHITE,
VESSEL IS ENGAGED IN TRAWLING.

RULE IS:q 6
CONCLUSION IS:
CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN DAYSHAPE IS CYLINDER,
VESSEL IS CONSTRAINED BY ITS' DRAFT.

RULE IS:r 6
CONCLUSION IS:
CONTACT HAS SPECIAL STATUS.
WHEN THE FOLLOWING FACTS ARE TRUE:
WHEN DAYSHAPE IS DOUBLE CONES,
VESSEL IS ENGAGED IN FISHING OR TRAWLING.

RULE IS:/* 7
CONCLUSION IS:
REDUCE SPEED TO BARE STEERAGE-WAY. PROCEED WITH EXTREME
CAUTION UNTIL THE DANGER OF COLLISION IS OVER.
WHEN THE FOLLOWING FACTS ARE TRUE:
REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

APPENDIX D

INLAND RULES: CODED AND DECODED

RULE IS:s?!& 21

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 12 AND 4 AND 6 AND

RUN LTS ARE NOT COMPATIBLE. LIGHTS OR DAYSHAPES CAN NOT
NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY: FOG SIGNAL FWD OF BEAM.

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

DAYSHAPE IS BASKET.

RULE IS:s!& 20

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 12 AND 18 AND 4

ARE NOT COMPATIBLE. LIGHTS OR DAYSHAPES CAN NOT
NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY: FOG SIGNAL FWD OF BEAM.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

DAYSHAPE IS BASKET.

RULE IS:s?! 15

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 18 AND 6 AND 3 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED
VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY: FOG SIGNAL FWD OF BEAM.

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:@!? 10

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 6 AND 18

ARE NOT COMPATIBLE. LIGHTS OF ANY TYPE ARE NOT NORMALLY
DISPLAYED AFTER SUNRISE.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

RULE IS:@! 9

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 18 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:@? 8
CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 6 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE ARE NOT NORMALLY SEEN AFTER SUNRISE.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

RULE IS:#& 11

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 12 ARE NOT COMPATIBLE.

DAYSHAPES ARE NOT NORMALLY DISPLAYED AFTER SUNSET.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = NIGHT.

DAYSHAPE IS BASKET.

RULE IS:s& 12

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 12 AND 3 ARE NOT COMPATIBLE.

DAYSHAPES CAN NOT NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

DAYSHAPE IS BASKET.

RULE IS:s? 13

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 6 AND 3 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

WHEN SPECIAL LIGHTING CONFIGURATION IS:

RED OVER WHITE

RULE IS:s! 14

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 18 AND 3 ARE NOT COMPATIBLE.

LIGHTS OF ANY TYPE CAN NOT NORMALLY BE SEEN DURING REDUCED VISIBILITY CONDITIONS.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY:FOG SIGNAL FWD OF BEAM.

WHEN STANDARD LIGHTING CONFIGURATION IS:

STERN

RULE IS:#@ 19

CONCLUSION IS:

SEMANTIC ERROR.

SELECTIONS 1 AND 2 ARE NOT COMPATIBLE.

THE TWO POSSIBLE TIME-PERIODS CAN NOT OCCUR TOGETHER.

WHEN THE FOLLOWING FACTS ARE TRUE:

TIME = DAY.

TIME = NIGHT.

RULE IS:W 25

CONCLUSION IS:

REDUCE SPEED TO ENSURE SAFETY OF BOTH VESSELS. WHEN PASSING WITHIN 200 FT. OF CONTACT, REDUCE SPEED TO 5 MPH OR LESS.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ENGAGED IN SERVICING NAVIGATION AIDS.

RULE IS:L 25

CONCLUSION IS:

REDUCE SPEED TO ENSURE SAFETY OF BOTH VESSELS. WHEN PASSING WITHIN 200 FT. OF CONTACT, REDUCE SPEED TO 5 MPH OR LESS.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ENGAGED IN SERVICING NAVIGATION AIDS.

RULE IS:U 26

CONCLUSION IS:

WHEN WITHIN ONE MILE OF CONTACT, INDICATE INTENTION TO PASS WITH ONE LONG BLAST. CONTACT WILL DIRECT YOU TO PROPER SIDE FOR PASSAGE WITH ONE SHORT BLAST FOR A STBD PASSAGE OR TWO SHORT BLASTS FOR A PORT PASSAGE. ANSWER WITH SAME SIGNAL TO ACKNOWLEDGE. IF CONTACT SOUNDS DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO PASS. SLOW DOWN OR STOP AND AWAIT FURTHER SIGNAL.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ENGAGED IN LAYING CABLE.

RULE IS:N 26

CONCLUSION IS:

WHEN WITHIN ONE MILE OF CONTACT, INDICATE INTENTION TO PASS WITH ONE LONG BLAST. CONTACT WILL DIRECT YOU TO PROPER SIDE FOR PASSAGE WITH ONE SHORT BLAST FOR A STBD PASSAGE OR TWO SHORT BLASTS FOR A PORT PASSAGE. ANSWER WITH SAME SIGNAL TO ACKNOWLEDGE. IF CONTACT SOUNDS DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO PASS. SLOW DOWN OR STOP AND AWAIT FURTHER SIGNAL.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ENGAGED IN LAYING CABLE.

RULE IS:V 28

CONCLUSION IS:

MANEUVER TO AVOID A VESSEL AT ANCHOR.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ANCHORED.

RULE IS:P 28

CONCLUSION IS:

MANEUVER TO AVOID A VESSEL AT ANCHOR.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ANCHORED.

RULE IS:O 26

CONCLUSION IS:

WHEN WITHIN ONE MILE OF CONTACT, INDICATE INTENTION TO PASS WITH ONE LONG BLAST. CONTACT WILL DIRECT YOU TO PROPER SIDE FOR PASSAGE WITH ONE SHORT BLAST FOR A STBD PASSAGE OR TWO SHORT BLASTS FOR A PORT PASSAGE. ANSWER WITH SAME SIGNAL TO ACKNOWLEDGE. IF CONTACT SOUNDS DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO PASS. SLOW DOWN OR STOP AND AWAIT FURTHER SIGNAL.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ENGAGED IN DREDGING.

RULE IS:S 26

CONCLUSION IS:

WHEN WITHIN ONE MILE OF CONTACT, INDICATE INTENTION TO PASS WITH ONE LONG BLAST. CONTACT WILL DIRECT YOU TO PROPER SIDE FOR PASSAGE WITH ONE SHORT BLAST FOR A STBD PASSAGE OR TWO SHORT BLASTS FOR A PORT PASSAGE. ANSWER WITH SAME SIGNAL TO ACKNOWLEDGE. IF CONTACT SOUNDS DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO PASS. SLOW DOWN OR STOP AND AWAIT FURTHER SIGNAL.

WHEN THE FOLLOWING FACTS ARE TRUE:

THE VESSEL IS ENGAGED IN DREDGING.

RULE IS:A 24

CONCLUSION IS:

YOU MUST KEEP OUT OF THE WAY OF SAILING VESSELS UNLESS YOU ARE CONSTRAINED BY A NARROW CHANNEL. IF YOU ARE CONSTRAINED AND A CLOSE QUARTER SITUATION IS EMINENT, SOUND THE DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION.
WHEN THE FOLLOWING FACTS ARE TRUE:
CONTACT IS A SAILING VESSEL UNDER SAIL.

RULE IS:B 1

CONCLUSION IS:

YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.
WHEN THE FOLLOWING FACTS ARE TRUE:
CONTACT IS CROSSING FROM PORT TO STBD.

RULE IS:C 3

CONCLUSION IS:

YOU ARE GIVE-WAY VESSEL. MANEUVER TO AVOID CONTACT.
TURN STBD IF POSSIBLE.
SOUND ONE SHORT BLAST TO SIGNAL A STBD TURN.
WHEN THE FOLLOWING FACTS ARE TRUE:
CONTACT IS CROSSING FROM STBD TO PORT.

RULE IS:D 22

CONCLUSION IS:

BOTH SHIPS MUST GIVE WAY. GIVE ONE SHORT BLAST TO SIGNAL YOUR INTENTION TO ALTER COURSE TO STBD OR ANSWER THE CONTACT'S SIGNAL WITH THE SAME SIGNAL. DO NOT ALTER COURSE UNTIL YOU AND THE CONTACT HAVE MATCHED SIGNALS.

WHEN THE FOLLOWING FACTS ARE TRUE:
MEETING CONTACT HEAD TO HEAD.

RULE IS:E 23

CONCLUSION IS:

YOU ARE GIVE-WAY VESSEL. SOUND ONE SHORT BLAST IF YOU INTEND TO OVERTAKE ON THE STBD SIDE OR TWO SHORT BLASTS IF YOU INTEND TO OVERTAKE ON THE PORT SIDE. WAIT FOR THE SAME SIGNAL IN AGREEMENT BEFORE OVERTAKING. IF THE CONTACT ANSWERS WITH THE DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, DO NOT ATTEMPT TO OVERTAKE THE CONTACT.

WHEN THE FOLLOWING FACTS ARE TRUE:
OVERTAKING THE CONTACT.

RULE IS:F 27

CONCLUSION IS:

YOU ARE STAND-ON VESSEL. MAINTAIN COURSE AND SPEED.
ANSWER PASSING VESSEL'S INDICATION OF DESIRED SIDE TO PASS WITH SAME SIGNAL IF IT IS SAFE, BUT ANSWER WITH THE DANGER SIGNAL, FOUR OR MORE SHORT BLASTS IN RAPID SUCCESSION, IF THERE IS A DANGER.

WHEN THE FOLLOWING FACTS ARE TRUE:
BEING OVERTAKEN BY THE CONTACT.

RULE IS: * 7

CONCLUSION IS:

REDUCE SPEED TO BARE STEERAGE-WAY. PROCEED WITH EXTREME CAUTION UNTIL THE DANGER OF COLLISION IS OVER.

WHEN THE FOLLOWING FACTS ARE TRUE:

REDUCED VISIBILITY: FOG SIGNAL FWD OF BEAM.

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